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TRANSACTIONS

OF THE

NEW ZEALAND INSTITUTE,

1910.

ART. I.—*The Chemical Composition of Meat-extract.*

By A. M. WRIGHT, F.C.S.

[*Read before the Philosophical Institute of Canterbury, 2nd November, 1910.*]

IN spite of the fact that meat-extract has been in use as an article of diet since the time of Hippocrates, comparatively little has been known until recently of the chemical composition of this material. A review of the earlier literature on meat-extract shows that the methods of analysis used have been so varied, and in some cases so unreliable, that it is not possible to satisfactorily compare many of the results obtained. The greatest obstacle in the way of a thorough and careful study of meat-extracts has been the unsatisfactory condition of the analytical methods for determining the nitrogenous constituents upon which much of the value of a meat-extract depends. Recently, however, more exact and uniform analytical procedure has been adopted, and serves as a basis for obtaining data of the composition of this complex material, and for determining the comparative values of this product.

The object of this investigation was to determine as far as possible the complete chemical composition of meat-extract, and to ascertain which constituents increased and which decreased the commercial value of this material, it having been found that the earlier methods of analysis used in this laboratory did not satisfactorily reveal the differences in composition which could account for the varied value placed upon the extract in the London market, where a consideration of its colour, odour, and taste largely determines the price offered.

The fact that the complete analyses of New Zealand meat-preparations are not available makes the publication of the results obtained in this investigation desirable.

In an earlier paper* the author described the methods of analysis used in the study of the composition of a number of extracts, and in the course of this investigation the methods therein described for the determination of moisture, organic matter, mineral salts, chlorine, fat, and total nitrogen were used. The separation of the nitrogen and substances precipitated by 50, 60, and 80 per cent. alcohol has been discarded, as it is now found

* Journ. Soc. Chem. Ind., 1907, p. 1229.

that the results so obtained give no indication of the commercial value of the extract.

The following additional methods were used in this investigation :

Acidity.—Titrate a solution of 0·5 gram in 800 c.c. of water with deci-normal potassium-hydrate, using phenolphthalein as indicator; the result is then calculated and expressed in terms of acidity as lactic acid.

Insoluble and Coaguable Proteids.—For these determinations the provisional methods of the Association of Official Agricultural Chemists for meat fibre and coaguable proteids were used.*

Proteoses were determined by the zinc-sulphate method.†

Peptone-like bodies and polypeptides were precipitated together with the proteoses by the tannin-salt reagent, the amount of peptone-like bodies and polypeptides being found by difference.‡

Total Meat Bases.—From the nitrogen found in the tannin-salt filtrate deduct the nitrogen found as ammonia, the difference being the nitrogen as meat bases.

Ammonia was determined by the magnesium-oxide method.§

Purin bases were determined by Schittenhelm's method.||

Kreatin and kreatinin were determined by Follin's colorimetric method.¶

Phosphoric acid and potash were estimated in the residue from the ash-determination.**

The following table shows the composition of the extract examined :

—	1 per Cent.	2 per Cent.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.
Moisture	16·95	14·49	15·34	17·39	15·71	17·54
Organic matter ..	66·48	66·50	65·15	61·31	62·76	62·43
Mineral salts	16·57	19·01	19·51	21·30	21·53	20·03
Acidity, as lactic acid ..	11·20	12·60	11·10	10·90	11·60	11·00
Fat	0·33	0·40	0·42	0·41	0·35	0·45
Total nitrogen ..	8·47	8·87	8·12	7·88	8·05	8·31
Insoluble proteids ..	1·17	1·23	1·23	1·02	0·98	1·12
Coaguable proteids ..	0·38	0·68	0·64	0·42	0·17	0·16
Proteoses	11·41	15·49	14·39	11·81	11·19	10·21
Peptone-like bodies and polypeptides	9·80	5·40	6·27	10·69	10·99	10·45
Total meat bases ..	12·98	14·00	12·40	11·17	11·21	13·48
Kreatin and kreatinin ..	5·52	6·60	3·90	4·16	3·97	5·40
Purin bases	0·86	1·24	0·46	1·26	1·84	1·03
Other meat bases ..	7·60	6·16	8·04	5·75	5·40	7·05
Ammonia	0·82	0·90	0·66	0·64	0·75	0·52
Chlorine	1·87	2·52	3·07	2·68	3·05	2·71
Phosphoric acid ..	5·54	6·24	5·29	5·24	5·58	4·60
Potash	6·76	7·60	7·80	8·14	7·92	8·32

* U.S. Dept. of Agric., Bureau of Chem., Bull. 107, p. 115.
† *Ibid.*
‡ Journ. Amer. Chem. Soc., 1906, vol. 28, p. 1485.
§ U.S. Dept. of Agric., Bureau of Chem., Bull. 107, p. 9.
|| U.S. Dept. of Agric., Bureau of Chem., Bull. 90, p. 129.
¶ Zeit. Physiol. Chem., 1904, vol. 41, p. 223.
** U.S. Dept. of Agric., Bureau of Chem., Bull. 107, pp. 3, 4, and 11.

The following table shows the composition of the mineral salts of the extract examined :-

	1 per Cent.	2 per Cent.	3 per Cent.	4 per Cent	5 per Cent.	6 per Cent
Insoluble matter	1·32	1·02	0·88	1·12	0·24	0·82
Iron-oxide ..	0·24	0·30	0·28	0·41	0·22	0·19
Calcium-oxide..	1·24	0·28	1·12	1·37	0·94	0·82
Magnesia ..	0·27	1·34	0·76	0·88	1·04	1·13
Potash ..	40·81	39·98	39·98	38·21	36·74	41·53
Soda ..	6·52	7·24	8·10	12·12	9·25	10·32
Sulphur-trioxide	2·24	2·76	1·92	3·04	2·08	2·40
Phosphoric acid	33·48	32·82	27·11	24·60	25·91	22·96
Chlorine ..	11·27	13·25	15·73	12·54	14·16	13·52

The moisture-content as laid down by Liebig should not exceed 21 per cent. The total mineral salts, according to the same authority, should vary from 15 to 25 per cent. The mineral salts found in true meat-extracts are potassium-dihydrogen-phosphate, potassium-monohydrogen-phosphate, and the sulphates of calcium, potassium, and sodium, and the chlorides of sodium and potassium. Chloride of sodium is a minor constituent of meat-extract, the chlorine being present almost entirely as the potassium-salt. Salt is sometimes added to extract of meat in order, it is stated, to preserve the product, but the fact that it increases the profit is probably the greater incentive to its use.

In the extracts examined under the chemical control of this laboratory no added salt is found, and experience shows that non-salted extracts keep quite as well as those to which large amounts have been added. Since added salt is not necessary to keep extracts from decomposition, the addition of such can only be regarded as an adulteration.

König* states that the mineral salts, especially the potassium-salts, present in the meat-extract are valuable on account of their action on the nervous system.

Chittenden† finds that the content of potash-salts causes a quicker and stronger heart-beat.

The acidity of meat-extract, determined by using phenolphthalein as indicator, is calculated to lactic acid as a matter of convenience, and for the sake of comparison with other investigators.

It is recognized that the acidity of meat-extract is due to various constituents, but sarcolactic acid is the predominating acid. It has been suggested that a part of the acidity is due to the phosphates present, but it is probable that the principal salt of phosphoric acid is the secondary potassium compound, which is neutral to phenolphthalein.‡

Fat is a detrimental ingredient in a meat-extract, and if present in large amounts indicates an imperfect method of manufacture, and affects the keeping-quality of the extract.

* "Chemische Zusammensetzung Nahrungs-und Genussmittel," p. 236.
† Med. News, 1891, vol. 58, p. 716.
‡ Journ. Amer. Chem. Soc., 1908, vol. 30, p. 1563.

The total nitrogen in meat-extract varies from 6 to 9 per cent. However, in judging the value of an extract it is of importance to consider the forms in which the nitrogen exists rather than its total amount : it has been found by Chittenden* that while the nitrogen-content is high it is not available for the body's use as a food.

Insoluble proteids should not be present in large amounts : their presence in quantity indicates either the addition of meat-fibre or imperfect methods of manufacture. To add meat-fibre or other protein to a meat-extract only reduces the proportion of meat bases to which the extract owes much of its true value, and merely adds small amounts of nutriment at an unreasonable price.

Coaguable proteids are also found in small amounts in all meat-extracts. It is impracticable to prepare a meat-extract containing more than a very small amount of coaguable proteids, for the reason that in the process of evaporation the temperature necessary coagulates the proteid.

Proteoses include the albumoses and certain gelatinoids. Most of the nitrogen attributed to proteoses in meat-extract is due to gelatin or gelatoses, and, as these bodies have a very low nutritive value,† it is apparent that the claim of a high nutritive value for meat-extract rests upon very unconvincing evidence. It is certainly incorrect to suppose that because proteoses are present there must be considerable nutrient property in meat-extract.

Peptone-like bodies and polypeptides so described in this paper correspond with the nitrogen usually determined as and attributed to peptones, but, as the filtrate from the zinc-sulphate precipitate furnished negative results when submitted to the biuret test, it is apparent that no natural peptones are present in the meat-extracts examined. Other investigators have reported a similar experience, and for that reason the absence of peptones in meat-extracts has met with a more or less general acceptance.

While natural peptones are excluded, it is probable that the nitrogen found in this determination is largely due to the non-biuret-reacting polypeptides of Fischer,‡ these substances being intermediate between the peptones and amido acids.

Fischer has pointed out that the commercial product is very closely related to the natural peptones, and that peptones are essentially a mixture of polypeptides, and he has further pointed out§ that many of the polypeptides fail to give the biuret reaction.

As no true peptones are found in most meat-extracts, it is seen that the claims made concerning the nutrient value of meat-extracts on account of the presence of peptones cannot be substantiated.

It is to the mineral salts and meat bases that a meat-extract owes its true value. The mineral salts have already been discussed, but it is the meat bases that give meat-extracts their chief value. Their chemistry is most complex; physiologically the most important are kreatin and kreatinin, and the purin bases. The purin bases usually found are xanthin, hypoxanthin, adenin, and guanin. A considerable number of other meat

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* Med. News, 1891, vol. 58, p. 716.

† Amer. Journ. Physiol., 1907, vol. 19, p. 287.

‡ "Untersuchungen über Aminosauren Polypeptides und Proteine," p. 23.

§ *Ibid.*, p. 50.

bases have been isolated from meat-extract in recent years—namely, ignotin, oblitin, methylguanidin, carnomuscarin, neosin, novain, alanin, leucin, and glycocoll;* these are present in extremely small quantities, and it is impossible with our present knowledge to determine all of the meat bases in meat-extracts.

The meat bases are the products of the breaking-down of proteins in the vital processes of the body, and are excreted for the most part unchanged, and have little use as tissue-builders; neither do they produce heat or energy; they are therefore not foods.

Recent experiments† show that meat bases furnish relief to fatigued muscle, and are powerful exciters of gastric secretion. They are thus most valuable, in that they create an appetite and prepare the system for food and aid its digestion. The custom of preceding a meal with soup which contains these bases has therefore a strong physiological warranty.

Ammonia when in quantity indicates some degree of putrefaction. Probably some of the ammonia present is in combination with acids of the fatty series.

Recently preparations made from yeast have been placed on the market as substitutes for and adulterants of meat-extracts. While as far as the taste and appearance are concerned they resemble meat-extracts, they show marked chemical differences, and are in no sense true substitutes, since they lack the valuable constituents and stimulating properties of meat-extracts, and their salts and bases.

Yeast on hydrolysis yields extractives somewhat similar to those obtained from meat, and when evaporated by the open-pan process darkens and looks like extract of meat. Caramel is sometimes added to darken the colour.

The following is the analysis of a sample of this class of product sold in this country:—

	Per Cent.
Moisture	27·80
Organic matter	50·56
Mineral salts	21·64
Acidity, as lactic acid	7·60
Fat	0·20
Total nitrogen	4·98
Insoluble and coaguable proteid	1·18
Proteoses	1·75
Peptone-like bodies and polypeptides	10·00
Total nitrogenous bases	3·11
Kreatin and kreatinin	0·32
Purin bases	2·51
Other nitrogenous bases	5·28
Ammonia	0·26
Chlorine	4·25

As in the case of the meat-extracts examined, no natural peptones were found.

* Zts. Nahr. Genussm., 1902, p. 193; 1905, p. 528. Zts. Physiol. Chem., 1906, p. 412.

† Journ. Physiol., 1907, p. 163; Medicin-chir. Centrbl., 1893, p. 653: "The Work of the Digestive Glands," Pawlow, trans. by W. H. Thompson, 1902.

The low content of kreatin and kreatinin and the presence of the purin bases are characteristic of yeast-extracts.

Another characteristic is that the filtrate from the zinc-sulphate precipitate is cloudy in the presence of yeast-extract, whereas with true meat-extract the filtrate is clear."

According to Micko† the distribution of the purin bases is different in meat and in yeast extracts: in meat-extracts xanthin and hypoxanthin predominate, while in yeast-extracts adenin and guanin predominate.

Formerly it was supposed that meat-extracts represented the whole nutritive value of the meat from which they were prepared, but from a consideration of their chemical composition as shown by more exact analytical procedure it is difficult to see whence their food-value could come.

Liebig's views are clearly stated by himself, as follows‡: "Neither tea nor extract of meat is nutriment in the ordinary sense; they possess a far higher importance by certain medicinal properties of a peculiar kind. . . . It is surely a grave offence against all the laws of physiology to compare tea, coffee, and extract of meat with the more common articles of food, and, because they are not that, to draw the inference that they are nothing at all."

It is thus clear that extract of meat was never intended by Liebig to be regarded as a concentrated food, having but comparatively little nutritive value. It is only fair to state, however, that many manufacturers make no claim as to its food-value.

There is little doubt that extract of meat is most valuable as a dietary adjunct, in that it arouses appetite and aids the digestion of any food with which it is taken, by acting as an excitant of gastric secretion; it further acts as a rapid and powerful restorative in condition of muscular fatigue. These are its true functions both in health and in disease.

For permission to publish these results the author desires to express his thanks to the Christchurch Meat Company (Limited), in whose chemical laboratory most of the work in connection with this investigation was carried out.

* Arch. Pharm., 1904, vol. 242, p. 537.
† Ber. deut. Chem. Ges., 1894, vol. 27, p. 499.
‡ The *Times*, 1st October, 1872.

ART. II.—*On certain Changes in the Composition of the Nitrogenous Constituents of Meat-extracts.*

By A. M. WRIGHT, F.C.S.

[Read before the Philosophical Institute of Canterbury, 2nd November, 1910.]

DURING the processes of manufacture of meat-extract considerable changes in the composition of the nitrogenous constituents take place. In the first place, the meat from which the extract is prepared is in contact with hot water for some time, and this, in conjunction with the sarcolactic and other flesh acids, and with the salts present in muscular tissue, causes a certain amount of hydrolysis to take place. The collagen of the muscle-fibre on hydrolysis yields gelatine, and by further hydrolysis soluble gelatin and other gelatinoids; similar action on the albumin yields small amounts of albumoses. Secondly, during the concentration of the extract-liquor by evaporation further changes in composition take place.

A liquor showing the following analysis was concentrated :—

	Per Cent.
Moisture	95·02
Organic matter	4·07
Mineral salts	0·91
Acidity, as lactic acid	0·50
Total nitrogen	0·488
Insoluble and coaguable proteids	0·165
Proteoses	0·838
Peptone-like bodies and polypeptides	Nil
Total meat bases	0·886
Ammonia	0·054

Calculating these results to correspond with an extract containing 20 per cent. of water, the following composition is shown :—

Moisture	20·00
Organic matter	65·60
Mineral salts	14·40
Acidity, as lactic acid	8·00
Total nitrogen	7·82
Insoluble and coaguable proteids	2·65
Proteoses	13·34
Peptone-like bodies and polypeptides	Nil
Total meat bases	14·19
Ammonia	0·85

After concentrating the liquor in the usual way by open-pan evaporation for forty-eight hours at 212° Fahr. the composition of the resulting extract calculated on a 20-per-cent.-moisture basis is as follows :—

Moisture	20·00
Organic matter	60·48
Mineral salts	19·52
Acidity, as lactic acid	10·30
Total nitrogen	7·92
Insoluble and coaguable proteids	1·16
Proteoses	12·37
Peptone-like bodies and polypeptides	8·69
Total meat bases	12·53
Ammonia	0·80

It is thus apparent that some considerable change had taken place in the composition of the material.

A portion of the same original liquor was concentrated under a partial vacuum of 15 in. at 180° Fahr. for three hours and a half, and the composition of the resulting extract calculated to a 20-per-cent.-moisture content shows:—

	Per Cent.
Moisture	20·00
Organic matter	63·01
Mineral salts	16·96
Acidity, as lactic acid	8·20
Total nitrogen	7·86
Insoluble and coaguable proteids	2·63
Proteoses	13·08
Peptone-like bodies and polypeptides	0·31
Total meat bases	13·76
Ammonia	1·08

It is seen that when the liquor is evaporated under vacuum there is some change in the composition of the resulting extract—the proportion of the organic matter decreases, while the mineral salts increase; otherwise the composition of the vacuum-evaporated extract is very nearly that of the original liquor calculated to a 20-per-cent.-moisture content, the acidity, insoluble and coaguable proteids, proteoses, and total meat bases being present in about the same amounts in each case. In the original liquor there were no peptone-like bodies, whereas in the vacuum-concentrated extract there were found 0·31 per cent. of these substances.

The extract concentrated in the open pan is very different in composition from either the original liquor or the vacuum extract: the proportion of the organic matter has decreased, and the mineral salts increased considerably; the total nitrogen remains about the same, but the forms in which the nitrogen is present have undergone considerable change; about three-fifths of the insoluble and coaguable proteids have been rendered soluble and converted to other nitrogenous substances; there is a decrease in the amounts of proteoses and meat bases: while against these decreases there is found 8·69 per cent. of peptone-like bodies which are absent in the original liquor, and present in the vacuum extract to only 0·31 per cent. The acidity has increased by over 2 per cent.

The peptone-like bodies and polypeptides are bitter in taste, and it is found that extracts containing relatively large amounts of these bodies have a decidedly bitter taste. Samples containing 16·58 per cent., 12·02 per cent., 14·65 per cent., and 13·43 per cent. of peptone-like bodies were found to be bitter, while in samples containing 8·44 per cent., 8·60 per cent., 8·69 per cent., and 5·09 per cent. of these bodies no bitter taste could be noticed.

As but very small amounts of peptone-like bodies are present in vacuum-concentrated extract, and but little change in the composition of nitrogenous bodies is found, it is probable that the prolonged action of heat on the nitrogenous material in the presence of the normal flesh acids and salts, the amount of which increase as the evaporation proceeds, is the cause of the marked change in composition found in the open-pan-concentrated extract. The so-called "burned" flavour sometimes found in meat-extracts is doubtless due to the same cause, for in vacuum-concentrated extract no such undesirable flavour is noted.

For permission to publish these results the author desires to express his thanks to the Christchurch Meat Company (Limited), in whose chemical laboratory most of the work in connection with this investigation was carried out.

ART. III.—*The First-noted Occurrence of Pentathionic Acid in Natural Waters.*

By J. S. MACLAURIN, D.Sc.

[Read before the Wellington Philosophical Society, 5th October, 1910.]

PENTATHIONIC acid is readily formed by passing hydrogen-sulphide into a solution of sulphur-dioxide, but, though well known to the chemist, it has not previously been found in natural waters. This may be due to the fact that in ordinary analyses of mineral waters no special search is made for such compounds. Some account of the circumstances that led to the discovery of the acid should therefore be of interest.

The water in which it was found was obtained from a lake on White Island. This island, which is the summit of a volcano, lies in the Bay of Plenty, about thirty miles from the mainland. The lake covers an area of approximately 15 acres, and has a mean temperature of about 110° Fahr. The water is of a very unusual character, containing a great variety of salts and an enormous amount of free hydrochloric acid. In examining it for iodine by the well-known potassium-nitrite test, the author noticed the formation of a brown colour, which suggested the presence of a ferrous salt, but on titrating with potassium-permanganate more permanganate solution was used than the iron (previously determined gravimetrically) could require, even if all in the ferrous state, and, judging by the colour of the water, much of the iron was in the ferric state. There was no organic matter to cause this excessive reduction, and on adding decinormal iodine solution no appreciable action took place, showing that the reduction could not be caused by sulphur-dioxide or hydrogen-sulphide. On precipitating with excess of barium-chloride to free from sulphate, filtering off the $BaSO_4$, and heating with bromine water, a further precipitate of $BaSO_4$ was formed, showing that some sulphur compound was present. It seemed probable that this was one or more of the polythionic acids—most probably pentathionic acid, because of its greater stability. In order to prove the truth or otherwise of this surmise the water was boiled with mercuric cyanide (Debus, Jour. Chem. Soc., 1888, p. 288). The reaction between mercuric cyanide and pentathionic acid is as follows: $Hg(CN)_2 + H_2S_5O_6 = HgS + S_2 + 2SO_3 + 2HCN$. If the Hg in the precipitate ($HgS + S_2$) be determined, the equivalent amount of H in the $H_2S_5O_6$ can be calculated, and by precipitating the SO_3 in the filtrate as $BaSO_4$ the oxygen and part of the sulphur can be estimated. The remainder of the sulphur can be determined in the $HgS + S_2$ precipitate. The results so obtained for H, S, and O approximated roughly to the formula $H_2S_5O_6$. The oxygen was, however, too high, and it was thought probable that this was due to the oxidizing action of the ferric chloride and hydrogen-chloride present in considerable quantities in the water. Attempts to remove these substances were at first unsuccessful. The iron could not be precipitated by an alkali, since pentathionic acid is at once decomposed in alkaline solution; nor could the hydrogen-chloride be neutralized with a soluble alkali (soda, &c.), since momentary local supersaturation of the acid, with consequent decomposition of pentathionic acid, cannot be avoided. Precipitation of the iron as basic acetate was also tried, but this was not satisfactory. Finally the

difficulties were met by shaking up with slightly less magnesium-oxide than was necessary to neutralize the free acid and then precipitating the iron with potassium-ferrocyanide.

Although the hydrochloric acid could be nearly neutralized by this means, the chlorides so formed reacted with the mercuric cyanide, so that, instead of a precipitate of $HgS + S_2$, one containing a large proportion of $HgCl_2$ was obtained. This rendered the determination of the hydrogen in the pentathionic acid more difficult and less reliable than in the absence of $HgCl_2$. It was therefore decided to be satisfied with the approximate values for hydrogen already found, but to redetermine the sulphur and oxygen.

For this purpose 2,000 c.c. of the water was precipitated in the cold with slightly less barium-chloride solution than was necessary to throw down all the SO_3. After standing for twenty-four hours, the barium-sulphate was filtered off. The filtrate was divided into three portions, A, B, and C. In A the small amount of SO_3 still remaining was estimated by adding excess of barium-chloride and allowing to stand for twenty-four hours. This determination was made in the cold, because boiling causes slight decomposition of pentathionic acid. In B, the total sulphur was determined by oxidizing with bromine water and precipitating with barium-chloride. C was boiled with mercuric cyanide, filtered, and the SO_3 in the filtrate determined by boiling with solution of barium-chloride. By subtracting the amount of barium-sulphate obtained in A from the amounts found in B and C respectively, the S and O of the $H_2S_5O_6$ were readily calculated. The results so obtained gave $S_5O_{5 \cdot 92}$.

As the water is a very unusual one, the complete analysis will no doubt be of interest. It is as follows :—

	Per Cent.
Silica (SiO_2)	0·0080
Titanium-dioxide (TiO_2)	0·0030
Sulphur-trioxide (SO_3)	2·6534
Carbon-dioxide (CO_2)	0·0130
Phosphorus-pentoxide (P_2O_5)	Nil
Boron-trioxide (B_2O_3)	0·0310
Arsenious oxide (As_2O_3)	0·00056
Chlorine (Cl)	4·8210
Bromine (Br)	0·0034
Iodine (I)	Trace
Oxygen (basic) (O)	0·5306
Iron (Fe)	0·1456
Manganese (Mn)	0·0014
Aluminium (Al)	0·3330
Calcium (Ca)	0·1497
Magnesium (Mg)	0·0790
Potassium (K)	0·0884
Sodium (Na)	0·2154
Molybdenum (Mo)	Trace
Copper (Cu)	Trace
Ammonium (NH_4)	0·0091
Hydrogen in hydrochloric acid (H in HCl)	0·1328
Pentathionic acid ($H_2S_5O_6$)	0·0240
	9·24236

These results may be restated as follows:—

	Per Cent.
Ammonium-chloride (NH_4Cl)	0·0273
Potassium-chloride (KCl)	0·1654
Sodium-chloride ($NaCl$)	0·0379
Potassium-bromide (KBr)	0·0051
Potassium-iodide	Trace
Sodium-sulphate (Na_2SO_4)	0·6191
Magnesium-sulphate ($MgSO_4$)	0·3948
Calcium-sulphate ($CaSO_4$)	0·5090
Aluminium-sulphate ($Al_2(SO_4)_3$)	2·1090
Ferric sulphate ($Fe_2(SO_4)_3$)	0·2600
Ferrous sulphate ($FeSO_4$)	0·1976
Manganous sulphate ($MnSO_4$)	0·0038
Copper-sulphate	Trace
Molybdic acid	Trace
Silica (SiO_2)	0·0080
Titanium-dioxide (TiO_2)	0·0030
Boron-trioxide (B_2O_3)	0·0310
Arsenious oxide (As_2O_3)	0·00056
Carbon-dioxide (CO_2)	0·0130
Hydrochloric acid (HCl)	4·8338
Pentathionic acid ($H_2S_5O_6$)	0·0240
	9·24236

The water is remarkable for its complex character, and particularly for the very large amount of free hydrochloric acid which it contains. The presence of boron is interesting, more especially as it occurs in larger amounts than are found in some of the Tuscan waters used for the commercial production of boric acid.

ART. IV.—*The Conductivity of Aqueous Solutions of Carbon-dioxide prepared under Pressure at various Temperatures; with Special Reference to the Formation of a Hydrate at Low Temperatures.*

By C. M. STUBBS, M.A., 1851 Exhibition Research Scholar, Canterbury College.

Communicated by Dr. Evans.

[*Read before the Philosophical Institute of Canterbury, 2nd November, 1910.*]

INTRODUCTORY.

IT is well known that at ordinary temperatures carbon-dioxide is soluble in about its own volume of water, whatever be the pressure under which it passes into solution, the volume of the gas being measured at this pressure. Such an aqueous solution shows weak acid properties, giving, for example an acid reaction with phenolphthalein, and turning blue litmus purple. It is assumed in text-books that a compound H_2CO_3 is formed which ionizes as a weak acid into H^+ and HCO_3^-.

In order to ascertain what work had been done in connection with the acid properties of CO_2 solutions, a thorough search was made in all the available journals — viz., the "Journal of London Chemical Society," the "Philosophical Magazine," the "American Journal of Physical Chemistry," and "Zeitschrift für Physikalische Chemie." Nearly all the references were found in the first of these. It is very improbable that any valuable work done would escape notice in its abstracts; and, indeed, Walker and Cormack, reviewing in a preface to one of their theses the work known to them as having been done, mention none which is not referred to in this journal.

In searching the journals special attention was paid to the records of conductivity experiments, it being felt that the electrical conductivity method was much the best of approaching the subject of degree of ionization, if not the only practicable one. At the same time attention was paid to every detail concerning CO_2 solutions which could possibly bear on the subject, especially to solubility at different pressures and temperatures, and the formation of hydrates.

Bibliography.

The Combination of Carbon-dioxide and Water, Wroblewski, 1882 (Journ. Chem. Soc., vol. 42, p. 692).—The author (who first discovered the existence of a hydrate of CO_2) infers that a definite but readily dissociable hydrate exists "capable of existing only under certain pressures, increasing with the temperature, and equal to 12·3 atmospheres at 0° C."

The Composition of Hydrated Carbonic Acid, Wroblewski, 1882 (Journ. Chem. Soc., 42, 1026).—The author concludes that at a temperature of 0°, and under the pressure of about 16 atmospheres, CO_2 unites with water to form a hydrate $CO_2 8H_2O$.

Law of Solubility of Carbon-dioxide in Water at High Pressures, Wroblewski, 1882 (Journ. Chem. Soc., 42, 1021).—From this abstract it seems (*inter alia*) that the author had been able to form the hydrate only in small quantity, at the free surface of the solution, and the experiment seems to have been complicated by the freezing of the water.

The Electric Conductivity of Solutions of Carbon-dioxide, Pfeiffer, 1885 (Journ. Chem. Soc., 48, 212; original paper in Ann. Phys. Chem. (2), 23, 625–50, to which there was no access).—Pfeiffer was the first to definitely investigate the conductivity of CO_2 solutions under varying pressures. He worked with pressures of from 1 to 25 atmospheres, and apparently at ordinary temperatures. His results, in effect, were—(1.) Conductivity is in every case very small; under normal conditions it equals $\frac{1}{20}$ of that of spring water. (2.) If all the dissolved CO_2 were converted into ionized H_2CO_3 its conductivity should be more than 1,000 times as great as observed value. (3.) Change of pressure produces no alteration in the conductivity. (4.) Conductivity increases rapidly with increase of temperature; *cf.* with acetic and oxalic acids (this statement is not made at all clear in the abstract: temperature seems to be confused with dilution).

Conductivity of Aqueous Solutions of Carbon-dioxide, Knox, 1895 (Journ. Chem. Soc., 68, ii, 100).—Conductivity was determined by Kohlrausch's method, experiments being made at varying pressures, results being recorded for both rising and falling pressures, and at temperatures of 12·5° and 18°. All of his work appears to have been done with comparatively weak solutions, the most concentrated solution mentioned in the table of

recorded results (Journ. Chem. Soc., 77, 9) having a dilution 12·6, corresponding to less than 2 atmospheres pressure. He worked down to very great dilutions, and obtained a fairly satisfactory dissociation constant under these conditions.

The Dissociation Constant of Carbon-dioxide in Solution, Walker and Cormack, 1900 (Journ. Chem. Soc., 77, 5).—These investigators worked along the same lines as Knox, with apparently more elaborate precautions to insure accuracy. They measured the conductivity of solutions of various concentrations, all at a temperature of 18°, the pressure of CO_2 in contact with the solutions never rising above atmospheric. The ordinary Kohlrausch method of determining conductivity was used, measurements being made with induction coil and telephone. The apparatus was of glass, and great care was taken to insure absolute insulation of electrodes, &c. Water for the experiments with a conductivity of $0{\cdot}7 \times 10^{-6}$ in Siemens units at 18° was used, being obtained by successive distillations (1) with alkali, (2) with phosphoric acid, and (3) alone, the last being conducted in chemically pure air.

Reference is made to Pfeiffer's and Knox's experiments. The solutions in Pfeiffer's experiments were prepared under pressure, and hence were too concentrated to be of service in fixing the dissociation constant of CO_2. (The same objection applies to the experiments described in this thesis, and consequently no attempt has been made to determine the dissociation constant.)

Knox's dissociation constant is calculated as $0{\cdot}380 \times 10^{-6}$, the authors' as $0{\cdot}304 \times 10^{-6}$, corresponding to a difference in actual conductivity of about 10 per cent. This result is considered as being due to the authors having used better conductivity-water and to their more accurate method of determining the concentration of CO_2 in the solution—viz., by titration with barium-hydroxide, as against Knox's measurement by means of the pressure of CO_2 in the solution. (The above-mentioned discrepancy between the results of good workers would seem to show the experimental difficulty in obtaining accurate results when working with very small conductivities.)

The conductivity imparted to pure water by exposure to atmospheric CO_2 is calculated to be $0{\cdot}65 \times 10^{-6}$ Siemens units. At this very small concentration 14·4 per cent. of the dissolved CO_2 exists in the ionized state.

The remainder of the paper and an addendum (Journ. Chem. Soc., 83, 182) discusses the relative proportions of dissolved CO_2 and un-ionized H_2CO_3 existing in the solution, but without coming to any very definite conclusion.

A Hydrate of Carbon-dioxide, Villard, 1895 (Journ. Chem. Soc., 68, ii, 44).—The author's experiments lead him to take $CO_2 6H_2O$ as the composition of the hydrate. It does not decompose below 0° (*cf.* with Hempel and Seidel, below).

The Absorption Coefficient of Carbon-dioxide in Water at 0°, Prytz and Holst, 1895 (Journ. Chem. Soc., 68, ii, 104).—The freezing-point of a saturated CO_2 solution at atmospheric pressure was determined, giving a depression of 0·156°. The calculated depression, assuming all the CO_2 to dissolve as such or as H_2CO_3, was 0·158°. Absorption coefficient at 0° = 1·7308.

Compounds of Carbon-dioxide with Water, Hempel and Seidel (Journ. Chem. Soc. 76, ii, 151).—By sealing solid CO_2 and water in a glass tube, allowing temperature to rise to ordinary temperature and then cooling, a CO_2 hydrate was crystallized out; at 8° it melted under the vapour-pressure

of liquid CO_2 in the tube, and at $-2°$ under atmospheric pressure. Composition given as CO_28H_2O or CO_29H_2O.

Other references which were looked up, but from which no further assistance was gained, were :—

On the Physical Peculiarities of Solutions of Gases in Liquids, Wanklyn (Phil. Mag., 1902, 3, 346).

On the Influence of Pressure on the Electrical Conductivity of Solutions (Journ. Phys. Chem., 1899, 3, 186).

Determination of Electrical Conductivity of Solutions with Direct-current Instruments (Journ. Phys. Chem., 1901, 5, 536).

The Lowering of the Freezing-point of Water produced by Concentrated Solutions of Electrolytes, and the Conductivity of such Solutions (Journ. Phys. Chem., 1903, 7, 311).

Variation of Electric Conductivity at Low Temperatures (Journ. Phys. Chem., 1903, 7, 407).

Summary.

From these abstracts the following summary may be made : –

(1.) Solutions of CO_2 in water, at least under certain conditions of temperature and concentration, contain a certain (comparatively small) number of ions, presumably, by analogy with other weak acids, and from the evidence of their chemical behaviour, consisting of H^+ and HCO_3^-, from a molecule of H_2CO_3.

(2.) The degree of ionization has been measured by means of the electrical conductivity at ordinary temperature and under pressures varying from 1 to 25 atmospheres (Pfeiffer) ; also at temperatures of 12·5° and 18°, and concentrations below $\frac{1}{20}$ normal, due to atmospheric pressure (Knox, Walker, and Cormack).

(3.) A fairly satisfactory dissociation constant, agreeing with Ostwald's dilution law, has been calculated for small concentrations. The degree of ionization under ordinary conditions is very slight, so that H_2CO_3 is a very weak acid.

(4.) At 0° and under high pressures a hydrate of CO_2 has been crystallized out, stable apparently only under certain corresponding conditions of temperature and pressure. The composition is doubtful—possibly CO_28H_2O.

Grounds of Research.

It will thus be seen that conductivity-determinations had been made only at the temperatures of 12·5° and 18°, and that high pressures had been employed by only one investigator, Pfeiffer, using from 1 to 25 atmospheres. One statement of Pfeiffer's seemed to call for investigation—namely, that at high pressures the conductivity was constant, being unaffected by change of pressure. This seemed so opposed to the ordinary behaviour of fairly concentrated solutions (a solution of CO_2 at ordinary temperatures and under 25 atmospheres pressure being roughly normal) that it was thought worth making a series of conductivity-determinations at 18°, both to settle this point and to check with previous work.

The conductivity of CO_2 solutions saturated under various pressures at 0° seemed to call for investigation, especially in view of the fact that at this temperature and high pressures a hydrate of CO_2 had been shown to exist, the properties of which, including its composition, had been only vaguely determined (*e.g.*, the discoverer, Wroblewski, stated in one abstract that at 0° the hydrate was formed at 12·3 atmospheres pressure, while in

another the pressure was given as 16 atmospheres ; even the composition was in doubt, being given as having 6, 8, or 9 molecules of water of hydration). It was anticipated that the formation of a hydrate should cause a very noticeable variation in the conductivity, and this anticipation was fully realized.

The work to be attempted consisted in—

(1.) Investigating the conductivities, at 18° C., of saturated solutions of CO_2 in water, under pressures ranging from 1 to 30 atmospheres.

(2.) The same, if possible, at 0°—*i.e.*, if formation of a solid hydrate did not interfere with the obtaining of a complete result.

(3.) Investigating, by means of the conductivity, the formation and properties of a CO_2 hydrate at various low temperatures and at various pressures.

(4.) Determining the variation in conductivity of CO_2 solutions due to a variation in temperature. (This could only be done to a limited extent in the available time.)

(5.) One or two other points of interest in connection with CO_2 solutions came up during the course of work, and will be referred to.

Apparatus and Method.

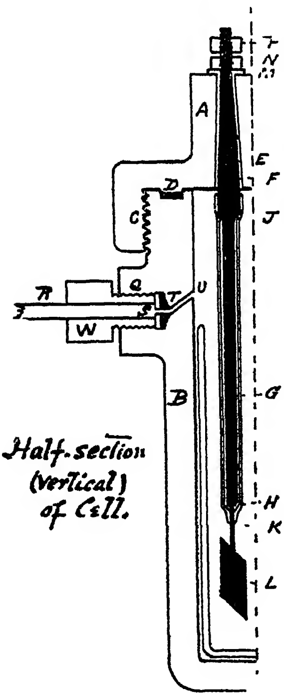
The ordinary Kohlrausch method of determining the electrical conductivity of solutions was adopted, using induction coil and telephone. Bridge-wire and known resistances were calibrated.

Conductivity-vessel.

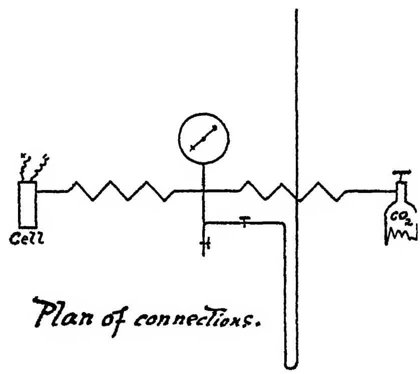
A special form of closed conductivity-vessel had to be used in order to stand the high pressures of the experiment. It was made of gun-metal, as it was not considered that glass would stand the pressure used. The only disadvantage attending this was that in the later stages of the experiment the interesting changes taking place within the vessel were not visible to the eye. The diagram on next page shows the details of construction.

The casting consisted of two parts—the vessel B, and the head A, which screwed on to B by the thread C. At D, fitting on to B was a broad lead washer, by screwing the head tight down on to which the apparatus was rendered absolutely gastight, even at the highest pressure. The head was bored with two slightly coned holes E to receive the electrodes F, G, H, L, the tops of which were coned at the same angle. Over the coned tops F of the electrodes pieces of the best rubber tubing were tightly stretched, the electrodes being then pulled home into their sockets ; this both made the electrodes perfectly steady and gastight, and also effectively insulated them. The electrodes, which were stout brass rods, tapered off from the shoulders J, and terminated in the platinum electrodes L. The exposed brass parts were encased in hard Jena-glass tubes which fitted tightly on to the shoulder at J. Into the ends H were soldered with silver-solder stout platinum wires, shielded by Jena-glass tubes sealed at K, and terminating in the electrodes L. The latter were made of heavy platinum sheet, measured each 20 mm. by 22 mm., and were placed from 8 mm. to 10 mm. apart, being closer at the bottom than at the top. They could be adjusted to a suitable distance by bending the platinum wires K, L. The ends of the electrodes protruding from the head were threaded to receive the nuts N and P. M was a thick fibre washer, acting as an insulator ; N a nut which was screwed down tight, thus pulling the electrodes fast into their sockets. P was another nut, which with N formed a binding screw for the lead from the electrode. The whole arrangement of electrodes was found to be quite steady and satisfactory from a conductivity point of view.

The aperture Q in B received the pipe R, through which CO_2 under pressure was forced into the cell. This pipe terminated in the flange S, which could by means of the nut W be forced home on a lead washer at T. The gas passed through a small hole in the washer, then through the passage U into the conductivity-vessel.



Half-section (Vertical) of Cell.



Plan of connections.

The details described made the vessel in practice perfectly gastight. The inside of the vessel was gold-plated, and an inner vessel of special Jena glass, manufactured for conductivity purposes, was placed within the outer plated one, which it fitted closely. As a further precaution, the part of the head near the shoulder J which was exposed above the solution was coated with insoluble enamel. (As a matter of fact, this was needless, as it was found in working that no water condensed on the head and upper part of the electrodes.)

Thus only the best Jena glass (beside the platinum electrodes) was in contact with the solution, and this glass was found to impart a definite but very small conductivity, which could be, and was, allowed for throughout the work.

Regulation of Temperature.

During the experiments conducted at 18° the electrolytic cell was immersed in a thermostat, fitted with a large toluol-mercury thermo-regulator and a centrifugal stirrer worked by a hot-air engine. This gave very satisfactory results, the temperature never varying by 0·05° on either side of 18°. For experiments at 0° the conductivity-vessel was immersed in crushed ice, which was frequently renewed. Probably the temperature of

the vessel rose to 0·5° at times even when immersed in the ice; but before taking a final reading in any experiment the temperature was always kept (by constant stirring) exactly at 0° till the reading assumed a constant value. The difference in solubility of CO_2 at the temperature slightly above 0° would be small, and would make (especially at higher pressures) a negligible difference in conductivity; so that by the above precautions it may be assumed that an accurate value of the conductivity was obtained. For the experiments at low temperatures other than 0°, ranging from —1° to 9°, the observer's continual presence was required to keep the temperature of the bath constant. The thermometer used was graduated to tenths of a degree, and the temperature was kept at the required point by the use below 0° of a salt solution and ice, and above 0° by adding small pieces of ice to the water, with constant stirring and watching the thermometer. In every case a final reading was taken only after keeping the temperature constant for a considerable time (at least thirty minutes), and making sure that readings were no longer varying.

STIRRING, ETC.

Owing to the form of the conductivity-vessel, the position of the electrodes, and the high pressure employed, it was deemed inadvisable to attempt to employ a stirrer in the solution; nor could a thermometer be introduced. The large mass of metal in the apparatus, however, insured that the temperature inside was the same as that of the thermostat. The absence of a stirrer was a drawback from a time point of view, as is was found that saturation at any pressure of CO_2, though aided by slight shaking of the apparatus and by convection currents, took twenty-four hours to accomplish.

Carbon-dioxide was obtained chemically pure from a bomb of liquid CO_2.

PRESSURE-GAUGES.

Two pressure-gauges used to determine the pressure of CO_2. The dial gauge was used for higher pressures; it was a new one of 8 in. diameter, and previous to use in the experiments was checked by a standard gauge.

For pressures less than 5 atmospheres an open mercury gauge was used. It could be connected at pleasure with the apparatus by means of a needle valve, and by it pressures could be read off in millimetres of mercury with great accuracy. By means of a screw below the needle valve the pressure in the apparatus could at any time be relieved to the desired extent.

CONDUCTIVITY-WATER.

As the electrical conductivity even of fairly concentrated solutions of CO_2 is very small—according to Pfeiffer, "about one-twentieth of that of spring water under normal conditions"—it was necessary to obtain by distillation water of special purity. Walker and Cormack, whose work has been referred to, obtained by three distillations a supply of water with a conductivity at 18° of $0{\cdot}7 \times 10^{-6}$ Siemens units, or about $0{\cdot}75 \times 10^{-6}$ reciprocal ohms. This appears to have been the best water used by any of the workers who have been referred to. Walker and Cormack worked with very dilute solutions where the conductivity was very small, and the relative effect of impurity in the water consequently great; it was therefore considered satisfactory for the purposes of the present experiments when a supply of water was obtained giving a conductivity of less than 1×10^{-6} ohms at 18° C. The supply was got by distilling in the open air with a modification of the Bousfield still. The distillate condensed on hard

Jena glass and dropped straight into the special collecting-flask. The water so obtained kept very well, showing a slight improvement after storage in an atmosphere free from carbon-dioxide.

Preparation of Electrodes, etc.

After the electrodes were in place they were cleansed thoroughly with chromic acid. They were then platinized in a solution of platinum-chloride and lead-acetate, a four-volt current being passed for twelve minutes, reversing every half-minute. To clean from the platinizing solution, they were then used as cathode for twenty minutes in dilute sulphuric acid, and afterwards thoroughly washed with distilled water. A good uniform coating of black was thus given, making the bridge-readings satisfactorily clear and definite.

The cell constant was determined in the ordinary way, using $\frac{N}{50}$ potassium-chloride solution as standard. (Here, as in the case of all solutions, the glass conductivity-vessel was filled up to a fixed height, sufficient to cover the electrodes half an inch or more.) Several determinations gave a mean value for the cell constant of 0·0833.

Experimental.

Altogether some six hundred readings were made, but of these only the final ones will be noted in this paper, unless for some special reason others leading up to them seem necessary. In making readings care was taken to note time, temperature, and gauge-pressure, as well as the bridge-reading.

Conductivities are expressed throughout in reciprocal ohms.

In most cases it was thought sufficient to determine the conductivity corresponding to every half-atmosphere pressure from 1 to $2\frac{1}{2}$ atmospheres, and to every five atmospheres from 5 to 30 inclusive.

Pressures are given as absolute values.

Dial-gauge readings were obtainable to well within a tenth of an atmosphere; mercury-gauge readings to one five-hundredth of an atmosphere.

Series I.

Temperature constant = 18° C. (± 0·05°) in thermostat; stirrer working continuously; cell immersed.

As fluctuations about the mean temperature were very small, producing only negligible variations in conductivity, the temperature throughout taken as 18° C.

Allowance made for half the conductivity of the water in calculating the conductivity of the solution; this done throughout. Calculations made as follows: If R denote the fixed resistance used, R′ the resistance of the solutions, c the conductance ($= \frac{1}{R'}$), C the specific conductance or conductivity, K the cell constant, x the bridge-reading:—

therefore $$R : R' = x : 100 - x$$

$$R\,(100 - x)$$

and $$C = \frac{Kx}{R\,(100 - x)}$$

Work done with descending pressures. Air withdrawn through mercury-gauge valve by a Fleuss pump. Valve then closed, and CO_2 allowed to fill the apparatus. This in turn withdrawn, and process repeated several times till all air thus swept out. Pressure put up to 30 atmospheres.

The following is a table of results (temperature 18° C.) :—

Pressure: Atmospheres.	Final Bridge-reading.	Resistance.	Conductivity.
30	40·6	300	$188{\cdot}6 \times 10^{-6}$
25	40·2	300	$185{\cdot}4 \times 10^{-6}$
20	38·32	300	$171{\cdot}2 \times 10^{-6}$
15	35·67	300	$152{\cdot}6 \times 10^{-6}$
10	32·1	300	$129{\cdot}9 \times 10^{-6}$
5	37·75	500	$99{\cdot}75 \times 10^{-6}$
2½	31·85	500	$76{\cdot}59 \times 10^{-6}$
2	30·35	500	$71{\cdot}35 \times 10^{-6}$
1½	28·55	500	$65{\cdot}33 \times 10^{-6}$
1	27·2	500	$60{\cdot}98 \times 10^{-6}$

The values obtained for the conductivity at different pressures disprove Pfeiffer's statement that conductivity does not vary with increase of pressure. These values lie on a regular curve which ascends very sharply from 0 to 1 atmosphere, and thereafter much more gradually. The influence of concentration on conductivity decreases fairly rapidly as the concentration increases, but does not vanish even at the highest pressure.

Series II.

Temperature = 0° C.

Work was begun with ascending pressure, and a complete range of values obtained. Subsequent work was under very varying conditions of temperature and pressure, such being called for by the observed phenomena.

The following table gives the first results (temperature 0° C.) :—

Pressure: Atmospheres.	Final Bridge-reading.	Resistance.	Conductivity.
1	28·4	1000	32·35
1½	31·6	1000	37·78
2	35·0	1000	44·15
2½	37·4	1000	49·06
5	29·15	500	67·82
10	34·85	500	88·38
15	38·0	500	101·4
20	39·35	500	107·4
25	41·0	500	115·1
30	41·8	500	118·9

So far the behaviour corresponded exactly to that at 18°, the conductivity being, of course, considerably lower. Wroblewski was said to have discovered a hydrate formed at 0° under pressures given as 12·3 or 16 atmospheres of CO_2, and it was anticipated that if such a hydrate existed there should be abnormal behaviour of the conductivity at these pressures; but such was not the case.

The pressure was now let down, the intention being to work with descending pressures over the same ground. For all future work the resistance used in the box was 500 ohms.

The following was the result :—

Date.	Time.	Pressure: Atmospheres.	Bridge-reading.	Conductivity.
Sept. 2	11 a.m.	25	41·35	116·7
,, 3	6.15 p.m.	20	33·0	..
,, 4	12 noon.	20	32·65	80·01
,, 4	10 p.m.	18	32·85*	..
,, 6	4 p.m.	18	31·85	77·11
,, 7	12.45 p.m.	16	30·8	73·45
,, 8	9.30 p.m.	14	30·9	73·8
,, 9	12.10 p.m.	12	30·9	73·8
,, 9	10.40 p.m.	10	32·1	..
,, 10	9.30 a.m.	10	31·9	..
,, 10	6.30 p.m.	10	32·4	..
,, 12	1 p.m.	8	33·65	83·8
,, 13	10.35 p.m.	5	30·2	71·4

* Temperature, 0·05°.

It is evident that somewhere between 25 and 20 atmospheres pressure of CO_2 a sudden change occurred in the nature of the solution, the conductivity undergoing a remarkable drop. As other experimenters had obtained evidences of a hydrate of CO_2 existing at low temperatures and high pressures, it was assumed that the change in conductivity was due to the formation of the hydrate.

The values of conductivity obtained at 25, 8, and 5 atmospheres pressure show that, apart from the influence of the hydrate, the conductivity of the solution under descending pressures follows closely that under ascending pressures, being in each case somewhat higher.

The remainder of the experiments consisted in an attempt to determine, by varying both pressure and temperature, such properties of the hydrates as capacity for super-cooling, temperature of transition under various pressures, degree of variation with temperature of conductivity of hydrate or of solution, &c. Though consecutive with Series II, they will for convenience be designated Series III, and in most cases details will be omitted.

Series III.

A. An attempt to determine the pressure under which formation of the hydrate would take place. Temperature, 0°.

Pressure very gradually raised to 30 atmospheres, with the following results :—

Time.	Pressure: Atmospheres.	Bridge-reading.	Conductivity.
..	10	34·13	85·6
..	11	35·25	90·0
..	12	35·9	92·6
..	13	36·45	94·8
..	14	36·95	96·9
..	15	37·35	98·6
..	16	37·9	100·9
..	17	38·2	102·3
11 a.m.	18	39 (about)	..

Hydrate not yet formed. Between 11 a.m. and 12.25 p.m. temperature kept at 0°. At 12.25 p.m. the following reading was obtained :—

Time.	Pressure : Atmospheres.	Bridge-reading.	Conductivity.
12.25 p.m.	18	34·8	..
12·35 p.m.	..	34·7	.
12·45 p.m.	..	34·6	.
12·55 p.m.	..	34·55	..
1 p.m.	..	34·4	..
4.15 p.m.	..	34·25	..
10.45 p.m.	..	34·2	85·9

During the formation of the hydrate the pressure remained constant.

Time.	Pressure : Atmospheres.	Bridge-reading.	Conductivity.
..	19	34·2	85·9
..	20	33·9	84·8
..	21	33·8	84·4
..	23	33·9	84·8
..	25	33·2	82·1
..	30	32·95	81·2

B. Pressure released from 30 to 25 atmospheres, temperature being kept low. A series of determinations of the conductivity with varying temperatures, at the constant pressure of 25 atmospheres. The hydrate decomposed between 4° and 10°, and was not re-formed when the temperature was lowered.

C. Temperature having been kept some hours at 0°, and hydrate apparently re-formed, the following series of readings was made (pressure = 25 atmospheres) :—

Temperature.	Bridge-reading.	Conductivity.
0°	33·2	82·8
4°	40·15	111·8
5°	42·1	121·2
6°	43·7	129·3
7°	45·5	139·1
8°	47·55	151·0
9°	48·55	157·1
13° *	50·9	172·7
18°	..	185·3

* Previously determined.

Each degree makes an average increase of $8{\cdot}5 \times 10^{-6}$ in the conductivity, till at about 8·2° a sudden break in the conductivity curve takes place, presumably due to all the hydrate having been decomposed. Thereafter the effect of raising the temperature is much less, on an average about 4×10^{-6} ohms per degree.

D. Pressure = 25 atmospheres. Readings with descending temperatures :—

Temperature.	Bridge-reading.	Conductivity.
9°	46·7	146·0
4°	42·7	124·2
2·1°	41·05	116·0
2°	37·35	99·3
1°	35·75	92·7
0°	34·0	85·8
1°	32·0	78·4

The hydrate formed suddenly at about 2·1° C.

E. Pressure released from 25 to 20 atmospheres, and a complete and consecutive series of determinations similar to the last made, using both ascending and descending temperatures. The hydrate which had been formed at 25 atmospheres was kept in existence by keeping the temperature low. The following results were obtained (pressure = 20 atmospheres) :—

	Temperature.	Bridge-reading.	Conductivity.
	0°	31·2	75·5
	1°	32·35	79·7
	2°	33·75	84·8
	4°	36·5	95·7
	5°	37·95	101·9
(*a.*)	..	38·8	105·6
	6°	42·7	124·2
	7°	44·2	131·9
	8°	46·5	144·7
	9°	47·2	148·9
	11°	48·8	158·8
	8°	46·4	144·2
	5°	43·6	128·8
	3°	41·75	119·3
	2°	40·8	114·8
	1°	39·8	110·1
(*b.*)	..	38·75	105·4
	0°	33·95	85·7

(*c*.) The temperature was now raised again.

Temperature.	Bridge-reading.	Conductivity.
4°	40·3	112·4
5°	41·8	119·6
6°	43·2	126·7
8°	46·5	144·7

The conductivity increased regularly with the temperature up to about $5\frac{1}{2}°$, when a remarkable variation made itself manifest. The conductivity first went down, and then suddenly rose, to the extent of over 2 cm. in the bridge-reading. This was repeated several times, the fluctuations gradually diminishing, the conductivity eventually assuming a constant value, much higher than would have been assumed if following the same law of variation as from 0° to 5°. This is shown in a graph by a vertical line at $5\frac{1}{2}°$. (During the fluctuations referred to the sound in the telephone was most interesting; the decrease in bridge-reading was fairly slow and uniform, but the increase was instantaneous, the telephone suddenly sounding a very loud note, and requiring the sliding contact to be moved a good deal higher before again being quiet.)

During the decomposition of the hydrate the indicated gauge-pressure rose by half an atmosphere. This is explained by the fact that the hydrate was formed at a higher pressure (25 atmospheres), and when it decomposed would yield an excess of CO_2.

From $5\frac{1}{2}°$ to 8° the conductivity continued to increase much in the same way as before, but then a break occurred, the conductivity thereafter increasing considerably more slowly with the temperature.

In lowering the temperature from 11° to 0° the conductivity obeyed the latter law of variation. It was therefore assumed that the solution remained as such, no change to hydrate form, with the corresponding phenomena, having taken place.

At (*b*), about 0°, the conductivity suddenly began to fall at an abnormal rate, eventually assuming the value given for 0°. This was taken to indicate that the formation of the hydrate had taken place.

The remaining part of the experiment (from *c*) was conducted several hours later. The pressure was in the meantime $20\frac{3}{4}$ atmospheres, not having been relieved after the evolution of the excess of CO_2. This will doubtless explain why the conductivity from $5\frac{1}{2}°$ to 8° was in this case slightly greater than in the former part of the experiment.

It was found here that there was no definite and sudden rise of conductivity, as there had been before. The graph of the conductivity is a continuous curve, almost a straight line, merging at 8° into the ordinary solution conductivity graph. Thus it seems that the abrupt change is characteristic only of those conditions under which a kind of stress exists in the hydrate, owing to its having been formed at a higher pressure than exists when it is about to decompose.

F. Temperature lowered to 0°; and, after bridge-reading had indicated formation of hydrate, pressure lowered to 15 atmospheres. Thus there would be in existence at 15 atmospheres a hydrate formed at

20 atmospheres, and the conditions would be similar to those of the last experiment. The values of the conductivity are given below, further explanation being unnecessary, the behaviour being quite similar to that under experiment *E*.

Temperature.	Bridge-reading.	Conductivity.
0°	33·2	82·8
2°	35·9	93·3
3°	37·2	98·7
4° *	39·9	110·6
6°	43·9	130·3
8°	45·3	137·9

* In this case the decomposition of the hydrate took place at 3°, being accompanied by the same phenomena of fluctation, &c., as in the last experiment, but on a smaller scale. There was also a second break at about 6°, the conductivity thereafter varying much less with temperature.

Conclusions.

1. At both 0° and 18° solutions of CO_2 in water are feebly ionized (about $\frac{1}{150}$ in the case of a $\frac{N}{10}$ solution at 18°); the conductivity increases with the pressure or concentration of CO_2 from 1 to 30 atmospheres, the proportional increase, however, becoming less the greater the concentration. Thus at 0° the conductivity at $4\frac{1}{2}$ atmospheres is about double, at 14 atmospheres about treble, and at 30 atmospheres less than quadruple its value at 1 atmosphere pressure.

This behaviour disproves the statement ascribed to Pfeiffer, that "change of pressure produces no alteration in the conductivity."

2. Temperature has a large effect on the conductivity, which at 8° to 9° is increased per degree by about 2·9 per cent. of itself.

3. After a CO_2 solution under high pressure has been kept for a few days there is a tendency for the solution to acquire a kind of chemical fixity or supersaturation, as shown by an increased value of the conductivity. Probably the CO_2 enters slowly into combination with water, the compound in its turn being only slowly decomposed.

4. A compound of CO_2 with water is formed under very varying conditions at low temperatures and high pressures.

(*a*.) The conductivity of the hydrate-bearing solution is considerably less than that of the free solution under similar conditions.

(*b*.) It crystallizes out with difficulty, there being a great tendency to a state in the solution resembling supersaturation with respect to the hydrate.

On one occasion the pressure was raised to 30 atmospheres and reduced again to between 25 and 20 atmospheres before the hydrate would form; on another it was formed in an apparently arbitrary way after the pressure had been for some time at 18 atmospheres; it was also formed at 15 atmospheres, and on another occasion could not be induced to form at all.

This tendency to supersaturation, and the element of chance consequent upon it, probably explains Wroblewski's varying observations, giving 12·3 atmospheres in one place and 16 atmospheres in another as the pressure under which the hydrate formed at 0°.

(*c*.) The conductivity of the hydrate-bearing solution, as has been stated, is less than that of the corresponding free solution, but it increases more rapidly than that solution in conductivity as the temperature is increased, eventually becoming equal to it in conductivity at some definite temperature (varying in the experiments performed from about 6° at 15 atmospheres to 8° at 25 atmospheres pressure). Henceforward the conductivity follows the conductivity-temperature law of the ordinary solution.

The similarity between the curve which expresses this behaviour and the vapour-pressure curves of ice and water intersecting at the transition-point is suggestive. Just as water can be supercooled, and its vapour-pressure curve produced below 0°, so the CO_2 solution seems capable of supercooling and the solution temperature-conductivity curve can be produced below the true transition-point.

(*d*.) As far as such evidence as was obtained can be relied on, in conformity with the statements in (*b*) above, the crystallization-point seems to occur at a lower temperature the lower the pressure: thus, at 25 atmospheres the formation of the hydrate took place at 2°, at 20 atmospheres pressure at 0°.

(*e*.) A hydrate formed at one pressure can be preserved at a lower pressure if the temperature be kept low; but when it melts, which it does at a definite temperature, it does so completely and rapidly, causing a sudden rise in the conductivity and increase in the pressure, due to evolution of the extra CO_2 held. The melting-point rises in such cases with increase of concentration: thus, the hydrate formed at 20 atmospheres and decomposed at 15 atmospheres melted at 3°, while that formed at 25 atmospheres and decomposed at 20 atmospheres melted at 5½°. This behaviour agrees fairly well with the observations of Hempel and Seidel, who found that the hydrate formed by them at a very high pressure—*i.e.*, the vapour-pressure of liquid CO_2—melted under this pressure at 8° and under atmospheric pressure at —2°.

(*f*.) At 0° C. the hydrate is decomposed at between 8 and 10 atmospheres pressure.

(*g*.) Wroblewski's statement that the hydrate is "capable of existing *only* under certain pressures, increasing with the temperature," is inaccurate, as the hydrate has been formed or kept in existence at 0° under pressures varying from 9 or 10 to 30 atmospheres. There is apparently a lower pressure-limit, but not a higher.

(*h*.) It seems certain from the facts mentioned in (*e*) that the composition of what has been styled "the hydrate" varies. There was no means of determining, however, whether more than one hydrate was formed.

ART. V.—*On the Velocity of Evolution of Oxygen from Bleaching-powder Solutions in Presence of Cobalt-nitrate, and the Modifications produced by the Addition of various Compounds.*

By N. M. BELL, M.A., Canterbury College.

[*Read before the Philosophical Institute of Canterbury, 2nd November, 1910.*]

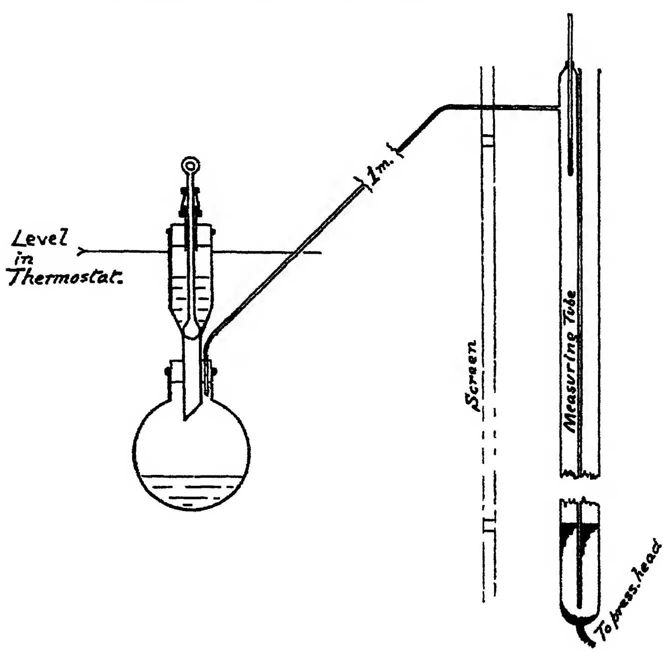
IN each experiment measurements of two kinds were made :—

1. The evolved oxygen was collected in a burette and the volume read at definite intervals.

2. The evolved oxygen was calculated by titrating the bleaching-powder with $\frac{N}{10}$ arsenious acid before and after the experiment. The results of the two methods agreed well.

The concentrations obtained from the two titrations inserted in the equation for a mono-molecular reaction gave the velocity.

The reactions were carried out in a 100 c.c. glass flask, the rubber stopper of which carried a short wide tube, conical at its lower part, and closed near the bottom by a glass-rod stopper ground in. This rod stopper passed through and was connected by a rubber-tube joint with a short glass guide-tube carried by a cork at upper end of the outer glass tube. The accompanying diagram shows the complete apparatus.



The evolved gas was carried off by a narrow glass tube over a metre long, arranged to condense and carry back into the flask any water-vapour formed. The flask was charged with 25 c.c. of bleaching-powder solution,

unfiltered, and containing 16 grammes per litre. The stoppered tube carried 5 c.c. cobalt-nitrate solution, 0·005 N to 0·00125 N, and in the first series of experiments 5 c.c. of water, in the second series 5 c.c. of the compound under examination. The flask and wide tube were immersed in a large thermostat with regulator and centrifugal stirrer. When the temperature became uniform the rod stopper was raised and the catalytic agent run in. Each experiment in the first series lasted about forty minutes. Somewhat over 400 experiments were carried out, apart from all preliminary work.

PART I.

Specimen Experiment: Measurement of Gaseous Oxygen evolved.

Taken, 25 c.c. bleaching-powder solution, turbid, 32 grammes per litre: 5 c.c. cobalt-nitrate, 0·00125 N; 5 c.c. water.

Time in Minutes.	Cubic Centimetres of Oxygen.	Volume / Time	Temperature. Burette.	Temperature. Thermostat.	Barometer.
4	3·1	0·73	10·1	78·3	761
8	5·9	0·67	10·1	78·3	761
12	8·0	0·49	10·1	78·3	761
16	9·4	0·33	10·0	78·3	761
20	10·8	0·33	10·0	78·3	761
24	12·0	0·28	9·9	78·3	761
28	12·9	0·21	9·9	78·3	761
32	13·8	0·21	9·9	78·3	761
36	14·4	0·14	9·9	78·3	761
40	15·2	0·19	9·9	78·3	761

Summary of Results with Bleaching-powder and Cobalt-nitrate.

1. The velocity is proportional to the concentration of the cobalt solution.
2. The measurable velocity proceeds as for a unimolecular reaction.
3. Increase of temperature increases the velocity. A rise of 10° C. almost triples the initial velocity.
4. Reversing the order of addition of the components alters the reaction-velocity.
5. Shaking alters the reaction-velocity.

The velocity varied slightly with different batches of solution.

For a solution containing 25 c.c. bleaching-powder solution, 16 grammes per litre; 5 c.c. cobalt-nitrate solution, 0·0025 N; and 5 c.c. water, K = 0·01993 (c.c. O per minute).

PART II.

In this part various additions were made to the cobalt-nitrate solution, and their effect on the reaction-velocity determined. A bleaching-powder solution refiltered after twenty-four hours, of which 10 c.c. = 17·5 c.c. $\frac{N}{10}$ arsenious acid was used, and was found to keep for weeks without change in titration-value, although the reaction-velocity diminished very slightly.

10 c.c. bleaching-powder solution; 5 c.c. cobalt-nitrate, 0·000156 N; and 5 c.c. aqueous solution of the compound investigated.

The experiments in most cases lasted twenty minutes. Twenty-seven compounds, including acids, alkalies, oxidizing and reducing agents, and salts, were tried.

Summary of Results.

1. Acids accelerate the evolution of oxygen, and this effect is proportional to the concentration of the hydrogen ion.

Example: 5 c.c. of 0·02 N hydrochloric acid added to the cobalt-nitrate solution doubled the velocity (from K = 0·0063 to K = 0·0141). In case of oxalic acid, 5 c.c. of 0·01 N acid had a slight retarding effect, whereas 5 c.c. of 0·02 N acid doubled the velocity as with other acids. This suggests some changes in the oxalic acid at great dilution.

2. Alkalies retard. The action is proportional to the concentration of the hydroxyl ions, and is forty times as great as that of the acids. 5 c.c. of 0·0005 N alkali halves the velocity.

3. Salts of the alkalies were practically without effect, even in relatively strong solutions—*e.g.*, 5 c.c. of N potassium-chloride had no very appreciable effect.

4. Salts of the heavy metals either accelerate or retard.

5. Copper-sulphate accelerates greatly. 5 c.c. of N copper-sulphate evolves chlorine plentifully. 5 c.c. of 0·001 N solution doubles the velocity.

5. Reagents such as sodium-sulphide, which, like the alkalies, precipitate the cobalt, retard the evolution of oxygen.

6. Oxidizing agents, such as ferric chloride and potassium-dichromate, gave no uniformity of action; their effects, also, were not proportional to their concentrations.

7. Nickel and iron salts are similar in their action on bleaching-powder to cobalt-salts, the effect of nickel being about equal to that of cobalt, while iron has only about 1½ per cent. of the effect of cobalt.

8. It is impossible to judge from the chemical analogues of a particular metal whether it will accelerate or retard the cobalt reaction.

No record of previous quantitative work bearing on this subject could be found in the "Journal of the Chemical Society," "Comptes Rendus," "Zeitschrift für Physikalische Chemie," and "Journal of Physical Chemistry."

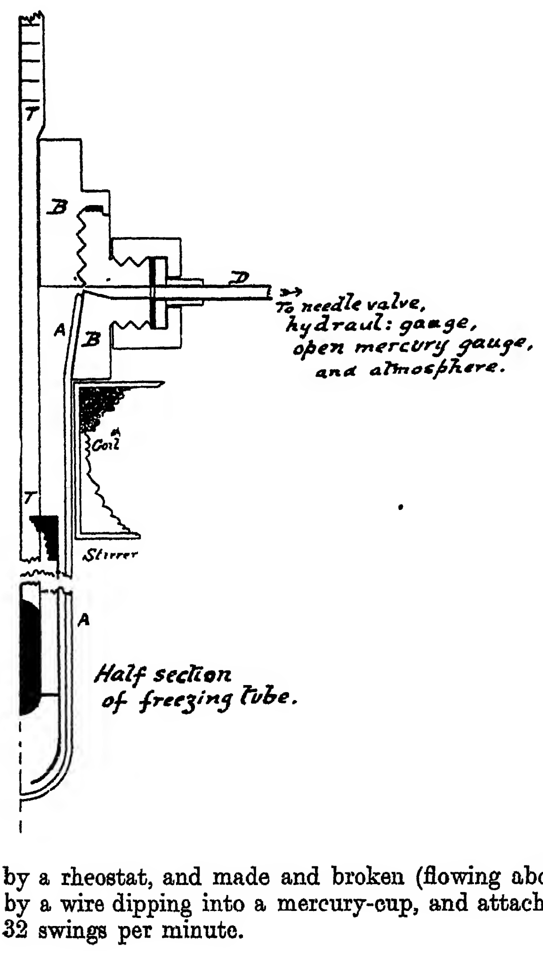
ART. VI.—*Depression of the Freezing-point of Water by Carbon-dioxide in Solution.*

By F. D. FARROW, M.Sc., Canterbury College.

[*Read before the Philosophical Institute of Canterbury, 2nd November, 1910.*]

THIS paper contains a brief account of the results of two series of experiments on the freezing-point of water containing carbon-dioxide in solution. The only work done in the same direction previously appears to be that of Garelli and Falciola.*

In the experiments now described the freezing was carried out in the thick glass tube A of the diagram, 28 mm. external diameter, widened slightly at the top. and sealed into the brass head B by means of a linen-tape collar and marine glue. B was connected by a copper tube D with the brass chamber E, and so with the pressure-gauge P, the carbon-dioxide bomb, the atmosphere through H, and an open mercury manometer M through the needle valve N [not shown in figure].



The water in A was stirred by a silver-wire stirrer soldered to a short cylinder of sheet iron 22 × 20 mm., which, after silver-plating, was covered with cycle-enamel and baked. This stirrer-ring enclosed the thermometer, and was raised and dropped by an intermittent current flowing in a coil of No. 18 copper wire, in 15 layers of 41 turns each, fitting loosely round the top of the glass freezing-tube. The current, 2-3 amperes, was adjusted by a rheostat, and made and broken (flowing about one-third of the time) by a wire dipping into a mercury-cup, and attached to a pendulum making 32 swings per minute.

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* Atti. R. Accad. Lincei, 1904 (v), 13, 1, 110–18. Abstract in Journ. Chem. Soc., 1904, vol. 86, ii, p. 312.

The temperature of tube and contents was controlled by a weak ice-and-salt solution in a felt-covered glass jar. The Beckmann thermometer was fitted by a stretched rubber covering-tube into a tapered hole, 13–15 mm. diameter, in a circular brass cap C, 62 mm. diameter, having a square top and screwing into a female screw on the head B, provided also with a recess containing a lead washer engaging with the flange projecting from the top of B.

The zero-point of the thermometer was found by inserting the bulb in distilled water contained in an ice sheath prepared by freezing distilled water round a Jena-glass tube and releasing the latter by warm water. A normal thermometer reading to 0·02° C., and known to be without appreciable error throughout the range employed, was treated similarly, and the two carefully compared up to about 5° C. in a continuously stirred water-bath of rising temperature.

The pressure-effect on the thermometer was considerable, and for the first thermometer used was not satisfactorily found, owing to its accidental destruction. Hence the first series of twenty experiments, otherwise perhaps the best, are not given here. For the second thermometer the pressure-effect was determined by filling the experimental tube with mercury, raising the pressure to the maximum, and taking simultaneous readings on thermometer and manometer as the pressure was progressively reduced. The curve plotted from the results is nearly a straight line. It is assumed that this line can be continued backwards to a point of no pressure.

On setting up the apparatus all air was driven out of the connecting tubes by a stream of carbon-dioxide, and out of the freezing-tube by saturating the contained water at 80 lb. pressure and removing the pressure. The gas evolved from the water in four or five such operations completely expelled the last traces of air. In each experiment, to insure saturation, the freezing-tube A was surrounded by ice-water, and the contained water stirred continuously some 15 to 30 minutes at a pressure about 10 lb. above that at which readings were to be taken. The gas was then allowed to escape until bubbles were evolved from the water. When, under continuous stirring, the manometer no longer rose, owing to gas evolved from solution, the temperature was reduced by a freezing-bath some 5° to 7° below final freezing-point. The formation of ice (in flakes throughout the solution) was followed by a sudden change in the click of the stirrer and by a rapid rise in the Beckmann thermometer. With the first thermometer used the temperature usually came to a final steady value, while the pressure slowly rose after freezing had progressed a little, owing to the gas frozen out of solution.

In the experiments taken as trustworthy the rise of pressure during freezing never amounts to more than 1 cm. of mercury. The pressure used in calculation is that shown during the steady period of thermometer, or an average of the pressures recorded if they varied for that period.

Series A, with Original Thermometer (20 Experiments).

Results are of qualitative value only, as, owing to an explosion, the pressure-effect on thermometer was not accurately determined.

Details of one complete experiment are given to show the method employed throughout the work. In Series B and Series C tables of corrected results only are given.

Freezing-point No. 2, Series A.

The freezing-tube surrounded with ice, and stirred under a slight excess of pressure for 15 minutes. Pressure then released by opening H. Gas given off from the water showing solution to be saturated. Stirring continued for 10 minutes, when rise of manometer no longer evident, and then cooling-bath brought under. Thermometer-readings every 15 seconds. Stirrer in motion throughout.

Thermometer.	Manometer.		Pressure: $b-a$	Thermometer.	Manometer.		Pressure: $b-a$
	a.	*b.*			*a.*	*b.*	
0·665	214	621	407	0·632	..	..	..
0·540	..	..	..	0·634	..	..	..
0·459	..	..	..	0·637	..	..	..
0·421*	215	621	406	0·638	212	623	411
0·460	..	..	..	0·639	..	..	..
0·530	..	..	..	0·639	..	..	..
0·565	..	..	..	0·639	212	623	411
0·590	213	622	409	0·639	..	..	..
0·609	..	..	..	0·639	..	..	..
0·617	..	..	..	0·639	..	..	..
0·621	..	...	..	0·639	212	623	411†
0·629	213	623	410				

* Freezing began at this point by formation of ice in flakes.

† After 3 minutes' stirring the temperature was again read. Two successive readings of 0·639 were obtained.

Atmospheric pressure	763 mm.
CO_2 pressure	411 mm.
Total	1174 mm.
Atmospheric temperature	10° C.
Pressure corrected for room-temperature ..	1172 mm.
Freezing-point	0·639
Correction of thermometer for pressure	0·222
Corrected freezing-point	0·417
Thermometer zero	0·586
Depression in degrees Beckmann	0·169
Depression in degrees Cent.	0·156
Depression calculated	0·142

SERIES B, WITH NEW THERMOMETER (19 Experiments).

This thermometer being rather short, the top of bulb came within 5 mm. of the lower plane of the stirrer-solenoid, while the water of the freezing-tube came up to this plane and was subject to some heating from the coil. The freezing-points were, in consequence, less definite than in Series A, the heating due to the stirrer-coil keeping the upper part of water always free from ice, and the temperature always showing a tendency to creep up.

Nineteen experiments were made, with total pressure ranging from 3277 mm. to 1432 mm. of mercury.

Table of Results, Series B, with Stirring.

Total Pressure of Carbon-dioxide in Millimetres of Mercury, corrected for Room-temperature.	Observed Depression / Calculated Depression = i
1432	0·88
1563	..
1622	0·70
1681	0·70
1688	0·84
1822	0·87
1897	0·85
2185	0·88
2189	0·76
2198	0·79
2218	0·87
2290	0·76
2342	0·76
2423	0·92
2670	1·14
2792	0·90
2794	1·13
2831	1·01
3271	1·16

The results, on the whole, show that the depression of the freezing-point for a stirred solution is about that which would be expected were all the dissolved gas present as carbon-dioxide molecules, and that at the higher concentrations a measurable amount of dissociation takes place.

Series C.

To avoid heating by the coil, now recognized as a disturbing factor, the latter was removed after saturation and the experiment was continued without further stirring. In all the experiments of this series (13) little gas was given off during freezing, even when this was complete. When the freezing-bath was removed gas was given off copiously from the solid ice, which appeared either to hold the gas in a solid solution or to be associated with a solid hydrate which decomposes on melting.

Table of Results, Series C, without Stirring.

Total Pressure of Carbon-dioxide in Millimetres of Mercury, corrected for Room-temperature.	Observed Depression / Calculated Depression = i.
752	1·19
762	1·05
1853	1·05
1979	1·32
2017	1·29
2195	1·21
2300	1·25
2320	1·07
2337	1·25
2412	1·10
2545	1·09
2696	1·29
2965	1·32

CONCLUSIONS.

The results seem to indicate—

(1.) That for a solution which is stirred while freezing the coefficient (i) is less than 1 for the lower pressures, and, increasing with rise of pressure, becomes greater than 1 at the higher pressures.

(2.) That for solutions not stirred the coefficient is always greater than 1, and increases with increasing pressure.

The only quantitative result found amongst earlier work is given by Garelli. He found that 0·35 grammes carbon-dioxide per 100 grammes water gave a depression of 0·165° C. The author's value for the depression at this concentration is 0·169° C., which agrees fairly well with that of Garelli.

ART. VII.—*On the Rate of Oxidation of Acetaldehyde to Acetic Acid.*

By D. B. MACLEOD, M.A., Canterbury College.

[*Read before the Philosophical Institute of Canterbury, 2nd November, 1910.*]

INTRODUCTION.

IN the 1894 number of the "Philosophical Magazine" an account is given of some experiments made by Dr. T. Ewan on the rate of oxidation of acetaldehyde to acetic acid, and the conclusion he comes to from his experiments is that aldehyde is oxidized to acetic acid in the vaporous state at a rate proportional to the concentration or pressure of the aldehyde and to the square root of the oxygen-pressure. This, however, did not seem to apply when the pressure of oxygen was above 450 mm. of mercury with the temperature at 20° C. In fact, he was unable to obtain any evidence of action with an oxygen-pressure of 599 mm. even when the temperature was 21·4° C.

The peculiarity of this sudden cessation of action, and the small number of the experiments of Dr. Ewan which are described, seemed to me to call for more experiments, as he himself says, to clear up this interesting behaviour. No record of the work having been continued either by himself or others could be found in the "Journal of the Chemical Society," the "Philosophical Magazine," the "Transactions of the Royal Society," the "Journal of Physical Chemistry," or the "American Journal of Science."

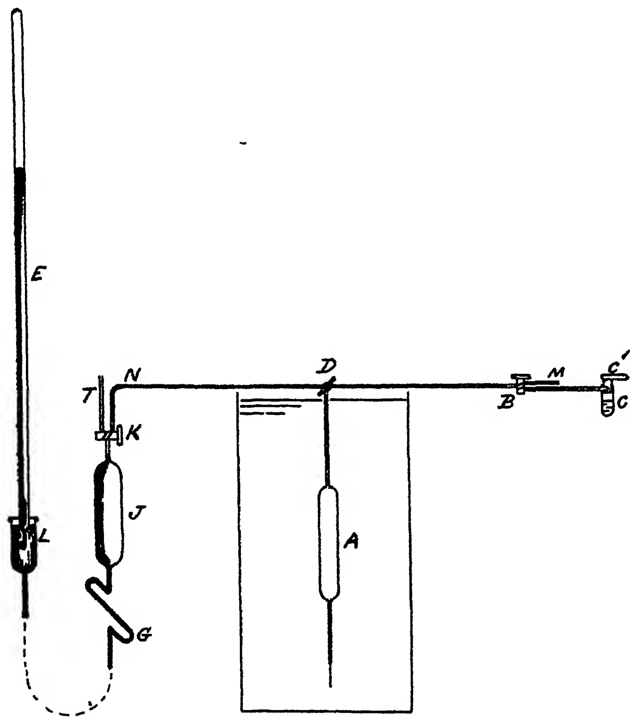
DESCRIPTION OF APPARATUS.

The apparatus used was in principle the same as that of Dr. Ewan, though with a few modifications, and is shown in the figure on the next page.

In Dr. Ewan's form of apparatus the mixture of aldehyde and oxygen was left in contact with the mercury, thus necessitating the use of bromnaphthalene to protect it, and also resulting in the volume of the reaction-vessel changing as the pressure decreased, the mercury altering its position

unless constantly rectified. Both of these difficulties were overcome by using a tap K, by means of which the mercury was shut off from contact with the aldehyde and oxygen, except for a few seconds while a reading was being taken. The tap K was a three-way tap the other limb connecting with the air.

The volume of the reaction-vessel thus remained constant, and the reaction could be allowed to proceed an indefinite time without further attention. The readings were always taken with the mercury just up to the tap. The tap used was of the Geissler form, this form being the best able to prevent leakage.



A second modification was made by putting an ordinary three-way tap at D. This was useful for several reasons. At the end of each experiment the whole of the hydrate solution was allowed to run in through the tap B. The three-way tap D could be so turned as to prevent the hydrate running along to the tap K, and so on to the mercury. The aldehyde was contained in a vessel C, with a tap C′. B is a single tap through which the oxygen was introduced. H is a mercury seal covering the junction of the pipette J with the mercury manometer. G is a trap to prevent air reaching the apparatus, if any should happen to leak through the indiarubber tubing. E is a barometer-tube, the lower constricted part of which dips under the mercury in L. The vessel L and the barometer-tube E could be moved up and down. The pressure in the vessel was thus obtained by reading the difference in height between K and E.

METHOD OF PROCEDURE.

In each experiment the mercury was first brought up to the tap K, the limb opening to the air being free. The tap was then closed, and the barometer and vessel lowered until the mercury in the barometer-tube was below the level of the tap K. The liquid aldehyde was then introduced into the vessel C, and the tap closed from the apparatus. The tube M was then connected with a vacuum pump, and with the tap D turned to connect all the ways with B the whole was evacuated. The tap B was then closed, and K turned to connect the mercury with the apparatus. Aldehyde was then allowed to distil into the reaction-vessel, which it did very readily, the mercury all the time being kept as near to K as possible. The vessel was then evacuated again, and this repeated three or four times, so as to completely replace the air by aldehyde. The final pressure of the aldehyde was taken, and the tap D turned so as to disconnect the right-hand part of the vessel, the reaction-vessel being only connected with the capillary tubing DLK The tap K was also closed. The capillary tubing DBM was then evacuated by means of the pump, and the tap B closed. M was then connected with a tube delivering pure oxygen dried over calcium-chloride. If the total pressure in the reaction-vessel was not required to be more than atmospheric pressure, the tap D was opened so as to connect all three ways, and, as soon as the oxygen had entered, the tap D was again turned, so as only to connect the tube DNK with the reaction-vessel, and the pressure read off. The tubing DB thus did not form part of the reaction-vessel.

If the pressure in the reaction-vessel was required to be greater than atmospheric pressure, the tap D was first turned so as to connect the tube DNK with the tube DB and disconnect the vessel A containing aldehyde. The mercury L was then lowered and the tap K turned. Oxygen was thus drawn over into the pipette J without aldehyde. The tap D was then turned to connect the vessel A with the pipette J, and the mercury head raised, driving the oxygen back into the reaction-vessel A. In this way any pressure obtainable on the gauge could be obtained in the reaction-vessel. The volume, also, not at the temperature of the bath was only that of the capillary tubing DNK.

At the end of each experiment the capillary tubing BD was first evacuated, and the tap B closed. Sodium-hydrate solution of known specific gravity was then allowed to fill the capillary tube. The vessel containing the hydrate was then weighed and again placed under B, the taps B and D being turned so as to let the hydrate into the reaction-vessel. The beaker containing the hydrate was again weighed, and the loss was that due to the hydrate drawn in. In this way the capillary tubing BD was filled with hydrate before both the first and second weighing, and hence introduced no error.

In the case where the final pressure in the reaction-vessel was greater than atmospheric pressure, the pressure was diminished by lowering the mercury head, and drawing some of the gas over into the pipette J, and finally driving it back when the hydrate had been introduced. The hydrate in a few minutes polymerized the whole of the aldehyde remaining, as the pressure soon became constant. Allowance had to be made for the vapour-pressure of the hydrate let in in determining the final pressure of oxygen.

When the whole of the aldehyde had been polymerized, the tap D was turned to disconnect DB, and a portion of the remaining oxygen and

nitrogen was drawn over into the pipette J by lowering the head and transferred into burette, and analyzed with alkaline pyro-solution in a Hempel pipette, to obtain the percentage of nitrogen present.

From the weight of hydrate drawn in, and the change of pressure after the hydrate had been let in, the quantities of aldehyde and oxygen at the end of the experiment could be calculated.

The volumes of the reaction-vessels used were between 90 and 100 cubic centimetres.

Importance of cleaning the Reaction-vessel.

Mention is made by Dr. Ewan of the fact that it seems to be of some importance to keep the apparatus as clean as possible. This was found to be of the utmost importance. The chief difficulty experienced with these experiments was that the aldehyde tended to decrease faster than it should, according to the equation

$$2C_2H_4O + O = 2C_2H_4O_2,$$

this being due, no doubt, to polymerization taking place. Aldehyde polymerizes readily in the presence of mineral acids, bases, and many salts, especially sodium-acetate, so that it is of the utmost importance that these should be absent. No reliable correction can be made for polymerization, and any experiment in which it was marked had to be rejected as practically worthless. At the same time, the presence of the polymeric form seemed to have a distinct retarding effect on the action, as will be shown later. For this reason, and to make the conditions strictly comparable, the reaction-vessel and the whole of the capillary tubing and vessel containing the aldehyde were invariably left to stand at least twelve hours, filled with a solution of potassium-permanganate and hydrochloric acid. The manganese-dioxide was removed by oxalic acid, and everything washed out with distilled water with the utmost care, and dried in a current of hot air.

Correction for Aldehyde dissolved in the Acid formed.

By means of a factor k', calculated from the excessive decrease of aldehyde as determined at the end of the experiment, on the assumption that this decrease is due to the aldehyde being dissolved in acetic acid according to Henry's law, Dr. Ewan has attempted to make correction for this error. The value of this correction seems to me to be doubtful. In the first place, the value of k' for any one temperature should be constant, whereas the value of k' varies from 0·00103 to 0·002873—that is, it is in one case almost three times as great as in another—while the temperature has only varied from 20·2° C. to 20·6° C. Further, this value of k' at 20·8° C. is 0·001767, or almost twice as great as at 20·6° C. This in itself is sufficient to show that Dr. Ewan's constant is a very uncertain factor. There can be little doubt that where the value of k' is at all great some of the decrease in the aldehyde has been due to polymerization.

Further, it is extremely unlikely that when such a vapour as that of aldehyde, so near its condensing-point, had once dissolved in the acetic acid under the fairly large pressures at the beginning of the experiment it would vaporize again as the pressure decreased.

In any case, in most of the experiments, the error due to the dissolving of aldehyde by acetic acid is small, because the quantity of acid formed is small, and the surface exposed is also small, as the acetic acid runs down into the drawn-off part of the pipette. In those cases in which

the aldehyde showed a decided decrease in excess of the oxygen it was assumed that polymerization had taken place, probably on account of traces of impurity in the vessel, and the experiment repeated The term k' was therefore neglected, thus greatly simplifying the equation, and introducing no great error. The work of calculating the results when k' is included is extremely laborious, and little is illustrated when once the principle of the action has been determined. The greatest error due to this will probably be noticed most in the final values of the constant, because there the pressure of the aldehyde is small, and an error of 4 or 5 mm. will be most felt.

GENERAL DISCUSSION OF THE EQUATION USED.

The equation for the direct oxidation of the aldehyde to acetic acid can be written either as

$$2C_2H_4O + O_2 = 2C_2H_4O_2, \text{ or}$$

$$C_2H_4O + O = C_2H_4O_2,$$

in the second case the assumption being that the action goes on between the oxygen atoms and the aldehyde molecules.

If the first equation were the correct representation, the action should proceed at a rate proportional to the square of the concentration of the aldehyde and to the pressure of the oxygen. The second equation suggests that the action proceeds at a rate proportional to the concentration of the aldehyde and to the oxygen atoms.

Everything points to the second equation being the correct one. The values of K′ worked out by this equation give, on the whole, good results, and although there seems to be disquieting differences between some experiments carried out under apparently the same conditions, yet this is probably due to there being some catalytic agent present affecting the action. For each experiment the value of K′ obtained is fairly consistent, and the experiments as a whole show a general consistency.

The equation used was practically the same as that of Dr. Ewan, except that k', the factor allowing for the aldehyde dissolved in the acetic acid formed, was not taken into account.

Let the partial pressure of aldehyde at the commencement of the experiment be A millimetres, that of oxygen B millimetres, and that of nitrogen N millimetres. P is the total pressure of the gas at any instant. Suppose that after T minutes x millimetres of oxygen have combined with $2x$ millimetres of aldehyde to form acetic acid. The pressure of oxygen will then be $(b - x)$ and that of aldehyde $(a - 2x)$. Also, there will be a certain pressure of acetic-acid vapour, which will be equivalent to the vapour-pressure of acetic acid at that temperature after the acetic acid formed has commenced to condense to liquid.

If, then, the action proceeds with a velocity proportional to the concentration or pressure of aldehyde and of the oxygen atoms, then

$$-\frac{dp'}{dt} = Kp'^{\frac{1}{2}}p_2,$$

where p' = partial pressure of oxygen,
p_2 = partial pressure of aldehyde,
$\frac{dp'}{dt}$ = rate of change of pressure of oxygen.

As Dr. Ewan has shown, the pressure of oxygen atoms should be proportional to the square root of the pressure of oxygen if the law of mass action holds strictly, and a state of equilibrium is assumed, for there is equilibrium between the oxygen atoms formed and the oxygen molecule. The equation therefore becomes

$$K'C_{(o_2)} = C_{(o)} \times C_{(o)} = C_{(o)}^2,$$

where $C_{(o_2)}$ and $C_{(o)}$ represent the concentrations of oxygen molecules and atoms respectively.

From this, then,

$$C_{(o)} = K'C^{\frac{1}{2}}_{(o_2)},$$

or the pressure of the oxygen atoms varies as the square root of the pressure of the oxygen molecules. The actual value of K′ will undoubtedly be very small, as the number of oxygen atoms present can hardly be great even under the most favourable conditions.

In integrating the equation

$$-\frac{dp'}{dt} = Kp'^{\frac{1}{2}}p_2$$

we put $$p' = b - x\,;\quad p_2 = a - 2x.$$

This gives $$-\frac{d\,(b-x)}{dt} = K\,(b-x)^{\frac{1}{2}}\,(a-2x),$$

or $$\frac{dx}{dt} = K\,(b-x)^{\frac{1}{2}}\,(a-2x),$$

and integrating it gives

$$Kt = -\frac{1}{2\left(b-\frac{a}{2}\right)^{\frac{1}{2}}}\log_e\frac{(b-x)^{\frac{1}{2}}-\left(b-\frac{a}{2}\right)^{\frac{1}{2}}}{(b-x)^{\frac{1}{2}}+\left(b-\frac{a}{2}\right)^{\frac{1}{2}}} + \text{constant},$$

or, writing the logarithm to the base 10, we get

$$\frac{Kt}{2.30} = -\frac{1}{2\left(b-\frac{a}{2}\right)^{\frac{1}{2}}}\log_{10}\frac{(b-x)^{\frac{1}{2}}-\left(b-\frac{a}{2}\right)^{\frac{1}{2}}}{(b-x)^{\frac{1}{2}}+\left(b-\frac{a}{2}\right)^{\frac{1}{2}}} + \text{constant}.$$

The constant is obtained from the condition that $x = o$ when $t = o$, and the equation is therefore

$$K't = -\frac{1}{2\left(b-\frac{a}{2}\right)^{\frac{1}{2}}}\log_{10}\frac{(b-x)^{\frac{1}{2}}-\left(b-\frac{a}{2}\right)^{\frac{1}{2}}}{(b-x)^{\frac{1}{2}}+\left(b-\frac{a}{2}\right)^{\frac{1}{2}}} + \frac{1}{2\left(b-\frac{a}{2}\right)^{\frac{1}{2}}}\log_{10}\frac{b^{\frac{1}{2}}-\left(b-\frac{a}{2}\right)^{\frac{1}{2}}}{b^{\frac{1}{2}}+\left(b-\frac{a}{2}\right)^{\frac{1}{2}}}$$

where $K' = \dfrac{K}{2.30}$.

The values of K′ given in the tables are calculated by means of this equation, and in each case are multiplied by 10^5.

Experimental Work.

There seems to be nothing more clear from my experiments than that the action is extremely susceptible to the influence of accelerating and retarding influences. Much time was lost in the early part of the work through the sample of aldehyde, prepared by repeatedly redistilling a stock sample, containing paraldehyde. The result of using this sample was that the action would not go on at a rate at all comparable with that which Dr. Ewan observed, though otherwise the conditions were the same. When compared with the results obtained later on with a pure sample the difference is at once apparent.

The following are some results obtained by using this sample. There can be no doubt that there was the pressure of aldehyde in the pure form there, as the para form, boiling at 121° C., could not give a very great pressure at 21 C., but the presence of the para form is small quantities hindered the action.

The value of k' is not calculated, as it is obviously worthless.

Time in Minutes.	p_2.	p'.	P.	Temperature.
0	246	850	1096	20·7° C.
182	246	850	1096	..
0	250	513	763	20·7° C.
360	..	..	741	..
0	220	198	718	20·6° C.
160	..	..	715	..
0	252	374	621	20·7° C.
988	..	..	638	..
0	303	321	624	25° C.
300	..	..	593	..
0	318	279	627	25° C.
180	..	..	615	..
0	306	391	697	25° C.
720	..	..	671	..

These experiments show that there has been little action going on. At first the aldehyde was not suspected; but when the oxygen had been used undried, and dried over calcium-chloride and sulphuric acid, and when the temperature had been raised to 25° C., and still the action did not proceed at a satisfactory speed, it was thought that the fault was due to the aldehyde.

A second sample of aldehyde was prepared from the original sample by distilling it with dilute sulphuric acid, so as to break down the para form present.

Three distilling-flasks were used. The first contained the mixture of dilute sulphuric acid and aldehyde, the second contained calcium-chloride in fairly large quantities, and the third was empty. All the flasks and connecting tubes were carefully washed and steamed out before being used, so as to remove any trace of acid or base which might polymerize the aldehyde. The flasks were arranged in series.

The second and third flasks were immersed in ice, while the bath containing the first flask was gradually warmed until the water boiled. The distillation was then stopped. The aldehyde distilled over very readily, being so volatile that some of it passed the second flask, and only condensed on reaching the third flask. Any water-vapour was condensed in the second flask and absorbed by the calcium-chloride. When the water round the first flask had boiled it was detached, and the aldehyde which had condensed in the second flask distilled into the third flask. The temperature was kept down to 25° C., and the latter half of the liquid in the second flask rejected. The purified aldehyde was then transferred into a well-stoppered bottle protected from light, which had been carefully steamed out. This sample held good throughout the series of experiments.

Experiments made to determine whether such a Maximum Pressure as that indicated by Dr. Ewan's Experiments did exist.

In this connection the chief points to be cleared up were: (1) Whether a maximum reaction pressure did exist; (2) whether the pressure of aldehyde had any effect on it; (3) the effect of temperature on this maximum pressure, if it was found to exist.

At the outset it may be said that although the rate of reaction, as indicated by the value of K′, seemed to diminish with higher pressures of oxygen, the pressure of aldehyde remaining constant, yet there was nothing to show that the action came suddenly to an end, as is indicated by Dr. Ewan's experiments. Further, as will be shown later, on raising the percentage pressure of aldehyde the value of K′ again rose, even though the oxygen-pressure remained high. Some explanation from theoretical considerations, as will be shown later, can also be given of the fact that the value of K′ is small when there is a big pressure of oxygen and a small one of aldehyde.

It will be as well at this stage to quote some experiments to illustrate this point.

Except where otherwise stated, the oxygen, prepared from potassium-chlorate and manganese-dioxide, was dried over calcium-chloride. No attempt was made to absorb the acetic acid formed.

Time in Minutes.	p_2	p'.	P.	Temperature.	K′.
0	349	414	783	20·85° C.	..
154	256	368	656	21° C.	2·2
203	219	350	601	21° C.	2·5
262	193	338	563	21·1° C.	2·4
318	171	327	530	20·8° C.	2·5
371	155	319	506	20·9° C.	2·4
444	135	309	476	20·9° C.	2·4
509	124	304	460	20·9° C.	2·3

Partial pressure of nitrogen = 20 mm.
Partial pressure of acetic acid = 12 mm.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	232	534	793	20·8° C.	..
198	176	506	721	20·8° C.	1·3
242	169	503	711	20·8° C.	1·2
284	162	499	700	20·8° C.	1·2

Partial pressure of nitrogen = 27 mm.
Partial pressure of acetic acid = 12 mm.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	229	598	850	20·8° C.	..
159	173	570	776	20·8° C.	1·4
826	69	518	622	20·9° C.	1·2

Partial pressure of nitrogen = 23 mm.
Partial pressure of acetic acid = 12 mm.

All the other experiments quoted were made in semi-darkness; but the last one quoted was made in absolute darkness. No alteration is, however, noticeable in the reaction.

In the next two experiments the oxygen was dried with concentrated sulphuric acid instead of calcium-chloride. In the first the effect seems to be to show a retardation, but the value of K′ rises again in the second. The extreme sensitiveness of the action to determining agents makes it very difficult to have the conditions exactly the same. In any case there can be no doubt that an action has been going on.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	242	592	870	20·9° C.	..
166	213	577	838	20·9° C.	0·8
219	203	573	824	20·95° C.	0·73
281	194	568	810	20·95° C.	0·71
336	186	564	798	20·9° C.	0·71
459	172	557	777	21° C.	0·70
668	140	542	730	21° C.	0·88
1370	62	505	615	20·9° C.	0·9

Partial pressure of nitrogen = 36 mm.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	240	765	1051	20·9° C.	..
173	203	747	1008	20·9° C.	1·2
284	157	724	939	20·9° C.	1·2
1030	95	693	846	20·9° C.	0·73

Partial pressure of nitrogen = 46 mm.

In the next experiment the oxygen was again dried over calcium-chloride:—

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	250	851	1125	21° C.	..
165	199	826	1061	21° C.	1·1
193	191	821	1048	21° C.	1·1
221	182	817	1035	21° C.	1·1
249	172	813	1021	21° C.	1·1
449	125	790	952	21° C.	1·1

Partial pressure of nitrogen = 24 mm.

The number of these experiments, in every case the action going on regularly puts it beyond doubt that the action is able to go on at pressures of oxygen above 530 mm., at least under some conditions. In one

experiment, to confirm that acetic acid was formed, at the end of the experiment, instead of letting in the hydrate, the reaction-vessel was taken out of the bath, and acetic acid was found in the bottom of the pipette. On breaking the end and letting the liquid out on blue litmus-paper the paper was turned red and the smell of acetic acid was very noticeable.

The results of these experiments are opposed to those of Dr. Ewan, for although the value of K′ shows a decrease with rise of pressure of oxygen there is nothing to show that the action does not go on at least up to very much higher pressures than were found by him. It does not, on the face of it, seem probable that an action which went on readily when the pressure of oxygen was 450 mm. should cease when the pressure was raised only another 100 mm. If there are any oxygen atoms present with the pressure at 450 mm., there seems to be no theoretical reason why they should not exist in at least almost as large numbers with the pressure at 550 mm., allowing that the external conditions are the same. It seems to me extremely probable that some retarding influence was present of which Dr. Ewan was unconscious. As has been pointed out, in the earlier experiments little or no action went on, on account undoubtedly of the presence of the paraldehyde, especially when the oxygen-pressure was at all high.

Thus, comparing the last experiment quoted with one with similar pressures, only using a different sample of aldehyde, the difference is at once seen :—

Time in Minutes.	p_2.	p'.	P.	Temperature.
0	246	850	1096	..
182	246	850	1096	20·7° C.

It is just possible that the sample used by Dr. Ewan was not free from paraldehyde. It must be noted also that the average value of his constant at 21° C., worked out by the same method as mine, is only 1·2, whereas mine is 2·2.

As will be shown in the next section, many other substances affect the speed of the action, showing how easy it would be for the conditions to be different when apparently the same.

Some Catalytic Agents affecting the Reaction.

1. The effect of impure aldehyde has already been shown by comparing the results obtained with two different samples. Nothing more need be said at this stage.

2. *Impurities in the Oxygen.*—The oxygen was kept in bell jars over water. To this water considerable quantities of sodium-hydrate were added, to dissolve out any traces of chlorine, or oxides of chlorine, which are evolved when manganese-dioxide and potassium-chlorate are heated. On one occasion pure water was used in the jars, and the oxygen used immediately it had been collected, before the traces of impurities had dissolved. The effect of this trace of chlorine was almost to stop the reaction. The conditions of the experiment were otherwise the same as they had been.

The following experiment illustrates this :—

Time in Minutes.	p_2.	p'.	P.	Temperature.
0	255	435	720	..
120	252	434	717	20·9° C.

Partial pressure of nitrogen = 30 mm.

On the next day, using the same sample of oxygen, which had meantime remained undisturbed over the water, the action went on a little more readily, though still much slower than formerly.

Time in Minutes.	p_2.	p'.	P.	Temperature.
0	266	425	713	20·9° C.
145	..	..	680	20·9° C.
199	..	..	667	20·9° C.
271	..	..	652	20·9° C.
343	..	..	643	20·9° C.
1362	198	396	628	20·9° C.

Partial pressure of nitrogen = 22 mm.

On shaking the water up to dissolve the chlorine, and allowing it to stand several days, on again using it the action went on with very great rapidity—greater, in fact, than that previously observed.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K'.
0	258	500	782	21° C.	..
181	142	443	621	21° C.	3·2
230	110	429	575	21° C.	3·4
254	98	422	556	21° C.	3·7
307	78	414	528	21° C.	3·7
409	60	406	502	21° C.	3·3

Partial pressure of nitrogen = 24 mm.

The speed of this reaction is somewhat remarkable. Nothing was noticed to account for it. It may be that more water-vapour was present than usual. These results show how susceptible the action is to disturbing effects, the impurities in the oxygen being undoubtedly the cause of the change in the velocity of the reaction in these cases.

3. *Vessel.*—The speed with which the action proceeds seems also to be influenced by the nature of the reaction-vessel. It has long been known that the form and nature of the vessel has considerable effect on the velocity of gaseous reaction and this affords another marked example of it. Two reaction-vessels were used, so as to enable an experiment to be made each

day, as the vessel required at least twelve hours for thorough cleaning. Hence, if only one were used, an experiment could not be left to proceed all night and then the same vessel used again the next day; but with two, every day could be made use of. No influence due to the first two vessels was noticed, but towards the end of the series of experiments one of them was broken. The new pipette showed a marked and consistent retarding effect as compared with the old one. Three experiments altogether were made in the new vessel, and corresponding ones in the old one, the effect in each case being the same. The temperature at which each pair was made was different, so that a wide range of conditions was covered.

The first of the following pairs of experiments quoted was made in the new vessel and the second in the older vessel.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	255	571	857	40° C.	..
109	160	527	753	40° C.	3·6
164	149	522	737	40° C.	2·7
223	145	519	730	40° C.	2·2

Partial pressure of nitrogen = 31 mm.
Partial pressure of acetic acid = 35 mm.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	254	512	798	40° C.	..
109	159	467	693	40° C.	3·9
142	140	457	664	40° C.	3·8
218	105	441	613	40° C.	3·7
405	61	419	547	40° C.	3·3

Partial pressure of nitrogen = 32 mm.
Partial pressure of acetic acid = 35 mm.

The second pair of experiments was made at 48·2° C. The same general effect is noticeable—namely, a fairly rapid falling-off of the speed of the reaction in the new vessel, and a much smaller value of K′ than with the old vessel.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	261	507	795	48·2° C.	..
140	132	447	657	48·2° C.	4·35
170	128·6	445·4	652	48·2° C.	3·76
200	126	444	648	48·2° C.	3·3
232	124	443	645	48·2° C.	2·8

Partial pressure of nitrogen = 27 mm.
Partial pressure of acetic acid = 51 mm.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K'.
0	267	496	789	48·2° C.	..
71	138	437	653	48·2° C.	8·9
85	118	427	622	48·3° C.	9·3
100	108	421	606	48·3° C.	8·8
115	101	418	596	48·3° C.	8·3
175	87	411	575	48·3° C.	6·1
205	80	408	565	48·3° C.	5·7

Partial pressure of nitrogen = 26 mm.
Partial pressure of acetic acid = 51 mm.

The next pair of experiments was made at 21° C.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K'.
0	254	846	1120	21° C.	..
200	219·3	828·7	1080	21° C.	0·55
222	212·6	825·4	1070	21° C.	0·63
254	207·3	822·7	1062	21° C.	0·63
285	200·6	819·4	1052	21° C.	0·63
315	195·3	816·7	1044	21° C.	0·67
486	173	802	1006	21° C.	0·68

Partial pressure of nitrogen = 20 mm.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K'.
0	250	851	1125	21° C.	..
165	199	826	1061	21° C.	1·1
193	191	821	1048	21° C.	1·1
221	182	817	1035	21° C.	1·1
249	172	813	1021	21° C.	1·1
449	125	790	952	21° C.	1·1

Partial pressure of nitrogen = 24 mm.

The fact of these three sets of experiments showing a consistent difference in the rate of the reaction is very strong evidence that the difference was due to the vessel. The conditions otherwise were exactly the same, and the vessels were cleaned in exactly the same manner—namely, by leaving them in a solution of potassium-permanganate and hydrochloric acid for twelve hours at least, and then washing out with oxalic acid and distilled water.

4. *Water-vapour.*—It is extremely probable that, as water-vapour has the effect of increasing the dissociation of oxygen molecules, its presence would accelerate this reaction. It had been hoped that an experiment might be made in which both the aldehyde and oxygen were dried abso-

lutely, but, while little difficulty was experienced in drying the vessel and oxygen by leaving them in contact with phosphorous pentoxide for a considerable time, the same could not be done with the aldehyde. The most effective drying agents are strongly basic or acidic oxides, or metals, such as sodium and potassium, which show a strong affinity for water.

Now, aldehyde is polymerized rapidly by mineral acids, bases, and many salts. In fact, the utmost precautions must be taken to prevent polymerization, and the presence of the polymeric form, as has been shown, affects the reaction. On this account attempts to obtain a perfectly dried sample of aldehyde have so far failed.

Could such an experiment be made, the result would probably show a great retardation, if not a total cessation of the action.

In view of the number of experiments quoted showing the influencing effects of many substances on the speed of the reaction, little further support is needed to affirm that the action is very sensitive to catalytic agents of all kinds. The experiments of Dr. Ewan can, however, be further quoted to support this.

Four experiments, having their constants worked out, are recorded in the "Philosophical Magazine." In the first experiment, with the temperature at 20° C., the value of K varies from 0·76 as a minimum to 1·27 as a maximum. This is a very low value, for which he gives no explanation. In the next experiment the value of K varies from 2·81 to 3·57; in the next from 0·96 to 3·18; and in another experiment, in which the initial pressure of oxygen was only 373 mm., well below his maximum, at which the reaction goes on constantly, and the initial aldehyde pressure 178·5, the constant begins at a maximum of 2·82, and falls rapidly to 2·59, and then to 2·34—in fact, in this experiment the reaction between the two last readings was extremely slow, as will be shown by quoting the experiment:—

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	178·5	373·0	559·3	..	
353	122·8	346·8	488·8	20·8° C.	2·82
421	118·2	344·6	481·8	..	2·59
501	114·2	342·7	476·1	..	2·34

It will be noticed that in the last eighty minutes the total pressure fell only 5·7 mm., whereas in the latter part of a previous experiment, with the oxygen-pressure at 409·1 mm. and the aldehyde pressure 119·1 mm., the pressure fell 95 mm. in 700 minutes, although this latter case includes pressures which should give a much slower rate on the average.

For these variations Dr. Ewan gives no explanation. He mentions that it seems of some importance to keep the apparatus as clean as possible, but he does not say why.

If we accept the idea that the action goes on between the aldehyde molecules and the oxygen atoms, there are two separate actions the speed of which catalytic agents could affect: there is, first, the breaking-up of the oxygen molecule; and, secondly, the combination of the aldehyde with the oxygen atom. It seems to me most probable that in most cases the first of these two actions is the one most affected. Under the most favourable conditions there could hardly be many atoms of oxygen present,

and any agent which tended to lessen the number would have a very marked effect on the speed of the action. Water-vapour is an example of an agent which favours the formation of atoms, and it is possible that paraldehyde-vapour has the opposite tendency.

In any case, the extreme sensitiveness of the action would lend support to the assumption that it is an indirect one, taking place between the oxygen atoms and the aldehyde molecules.

THE EFFECT OF DIFFERENT PERCENTAGE PRESSURES OF ALDEHYDE ON THE VALUE OF K′.

It can be seen from a glance at the experiments quoted that the value of K′ is smaller when the oxygen-pressure is high, the aldehyde remaining constant. It was found, however, that on raising the aldehyde-pressure to something more nearly equal to that of the oxygen-pressure the value of K′ again rose, even when the oxygen-pressure was high. This is further illustrated by experiments made at 25° C. and 30° C.:—

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	421	602	1060	20·8° C.	..
73	339	566	954	20·8° C.	2·2
130	278	541	868	20·8° C.	2·4
183	236	523	808	20·85° C.	2·2
231	207	510	766	20·8° C.	2·3
282	192	498	739	20·9° C.	2·3
309	181	493	713	21° C.	2·2
426	138	477	664	20·8° C.	2·0
582	112	465	626	20·8° C.	1·7
1286	60	438	547	20·8° C.	1·2

Partial pressure of nitrogen = 37 mm.
Partial pressure of acetic acid = 12 mm.

In this experiment, though the oxygen-pressure was 602 mm. at the commencement, the action went on rapidly, the value of K′ being practically the same as in the first experiment.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	298	475	790	24·8° C.	..
96	249	451	732	24·8° C.	2·1
154	215	434	681	24·8° C.	2·2
220	182	418	632	24·8° C.	2·2
259	165	410	607	24·8° C.	2·3
305	147	402	581	24·8° C.	2·3
435	137	397	566	24·8° C.	2·4
502	119	388	539	24·8° C.	2·3

Partial pressure of nitrogen = 17 mm.
Partial pressure of acetic acid = 15 mm.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	260	745	1039	25° C.	..
176	190	711	950	25° C.	1·4
407	158	695	902	25° C.	1·01
478	151	692	892	25° C.	0·91
1325	98	665	812	24·7° C.	0·63

Partial pressure of nitrogen = 34 mm.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	434	691	1165	25° C.	..
78	333	650	1038	25° C.	2·4
106	320	635	1010	25° C.	2·4
139	294	621	970	25° C.	2·6
220	267	608	930	25° C.	2·6
252	239	593	887	25° C.	2·9
390	145	546	746	25° C.	2·9
1106	36	493	584	24·7° C.	2·06

Partial pressure of nitrogen = 40 mm.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	253	469	734	29·9° C.	..
45	218	452	702	29·9° C.	3·3
65	203	444	679	29·9° C.	3·6
86	187	436	655	29·9° C.	3·6
130	153	420	605	29·9° C.	3·7
200	110	404	556	30° C.	3·8
444	63	375	470	29·9° C.	3·3

Partial pressure of nitrogen = 12 mm.
Partial pressure of acetic acid = 20 mm.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	259	692	987	30·1° C.	..
66	212	667	934	30·1° C.	1·7
144	173	649	876	30·2° C.	1·8
168	166	646	866	30·2° C.	1·7
239	151	639	844	30·2° C.	1·5
307	136	632	822	30·2° C.	1·5

Partial pressure of nitrogen = 34 mm.

The regularity of this variation calls for explanation. The constant K′ has been worked out on the assumption that the number of oxygen

atoms present is proportional to the square root of the oxygen-pressure, and that the action goes on only between the aldehyde molecules and the oxygen atoms. Now, according to the kinetic theory of gases, these oxygen atoms, if present, would be formed during the collision of two oxygen molecules, and the number formed would be proportional to the number of these collisions. At the same time, the number of molecules re-formed would increase as the number of atoms present increased, until a state of equilibrium would be reached. The value of K′ then, thus worked out, does not take into account the possibility of an oxygen molecule being split up on coming in contact with an aldehyde molecule, and perhaps, in some cases at least, oxidizing the aldehyde molecule at the same time. If this went on to any great extent, then the greater the percentage of aldehyde molecules to oxygen molecules present, the greater would be the excess of oxygen atoms present, caused by contact of aldehyde and oxygen molecules, over the calculated number. The effect, then, if this be a determining factor, of raising the oxygen-pressure and keeping the aldehyde constant would be to lower the value of K′; but on raising the aldehyde-pressure to something nearer to that of the oxygen the value of K′ would again rise. In other words, the value of K′ would be somewhat dependent on the percentage pressures of aldehyde and oxygen. In most of the experiments there seemed to be a more or less distinct lowering in the value of K′ as the proportion of aldehyde became less, on account of the more rapid decrease in the pressure of aldehyde.

At the same time, it must be remembered that at no time during the experiment is a state of equilibrium reached either between the formation of oxygen atoms from molecules and the re-formation of the oxygen molecules, or between the oxygen atoms and aldehyde molecules. Now, if the percentage pressure of aldehyde were great, then an aldehyde molecule would seize upon an oxygen atom in many cases as soon as it was formed —that is, before it had time to come in contact with another oxygen atom —and thus count in the determination of the equilibrium. Thus the fact that oxygen atoms are being removed continually from the sphere of action would prevent a state of equilibrium being reached, and could cause, for any particular pressure of oxygen, the number of oxygen atoms ready to combine with aldehyde molecules to be greater than that calculated from the assumption of a state of equilibrium. Also, the greater the pressure of aldehyde in comparison with that of oxygen, the more would this be felt. This, it seems to me, might be a very considerable factor, and it is hard to see why it should not have at least some effect.

There is another factor which might have some effect, though it would in all probability be slight, if noticeable at all. With higher pressures of oxygen the proportion of oxygen atoms to oxygen molecules would be less than with lower pressures of oxygen. For instance, suppose the pressure of oxygen molecules to be A millimetres in one case and B in another, the value of B being greater than that of A. The number of oxygen atoms in the two cases would be $KA^{\frac{1}{2}}$ and $KB^{\frac{1}{2}}$ respectively, and the proportion of oxygen atoms to oxygen molecules in the two cases would be $\frac{K}{A^{\frac{1}{2}}}$ and $\frac{K}{B^{\frac{1}{2}}}$ respectively—that is, in the second case, where B is greater than A, the oxygen atoms are more diluted with the oxygen molecules, which are for the purposes of the reaction inert. This diluting of the reacting substances—namely, the aldehyde molecules and the oxygen atoms—by inert oxygen molecules might have the effect of retarding the action. Unless, however, we assume that time is taken up on collision—and the assumption

of the kinetic theory is that this factor is very small—this dilution should have little effect in reducing the number of collisions between aldehyde molecules and oxygen atoms. It is known that in solution the effect of some inert substance, as far as retarding the reaction is concerned, is very slight, and the same probably holds in the gaseous state. The effect of this factor, if at all noticeable, would be to reduce the value of K′ as the oxygen-pressure increased.

These seem to be the only possible determining factors from the theoretical standpoint, and if, as Dr. Ewan found, the action goes on readily with the oxygen-pressure at 450 mm., and ceases practically altogether with the pressure at 550 mm., no theoretical explanation seems forthcoming; in fact, it is almost inconceivable that so sudden a break should occur.

The Effect of Temperature on the Reaction.

The effect of rise of temperature on the reaction is, as would be expected, to increase the value of K′. At first increase of temperature by a few degrees seems to have very little effect, but at 50° C. the aldehyde is oxidized very rapidly, practically the whole being converted into acetic acid in the course of a few hours. There can be no doubt that the degree of dissociation of oxygen atoms becomes greater as the temperature rises, and this, together with the increased speed of the molecules, would account for the increased rate of oxidation. It was not considered necessary to make experiments at a temperature higher than 50° C., as little further would be illustrated, the speed at that temperature being sufficiently great to measure accurately. In the first experiment at 21° C. the proportion of aldehyde is rather greater than in the other cases, giving perhaps a higher value of K′ than otherwise.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	349	414	783	20·85° C.	..
154	256	368	656	21° C.	2·2
262	193	338	563	21° C.	2·4
371	155	319	506	20·9° C.	2·4
444	135	309	476	20·9° C.	2·4
509	124	304	460	20·9° C.	2·3

Partial pressure of nitrogen = 20 mm.
Partial pressure of acetic acid = 12 mm.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	298	475	790	24·8° C.	..
154	215	434	681	24·8° C.	2·2
220	182	418	632	24·8° C.	2·2
305	147	402	581	24·8° C.	2·3
435	137	397	566	24·8° C.	2·4
502	119	388	539	24·8° C.	2·3

Partial pressure of nitrogen = 17 mm.
Partial pressure of acetic acid = 15 mm.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	253	469	734	29·9° C.	..
45	218	452	702	29·9° C.	3·3
65	203	444	679	29·9° C.	3·6
86	187	436	655	29·9° C.	3·6
130	153	420	605	29·9° C.	3·7
200	110	404	556	30° C.	3·8
444	63	375	470	29·9° C.	3·3

Partial pressure of nitrogen = 12 mm.
Partial pressure of acetic acid = 20 mm.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	267	496	789	48·2° C.	..
71	139	437	653	48·2° C.	8·9
85	118	427	622	48·3° C.	9·3
100	108	421	606	48·3° C.	8·8
115	101	418	596	48·3° C.	8·3
175	87	411	575	48·3° C.	6·1
205	80	408	565	48·3° C.	5·7

The fact that the rise in the value of K′ is not regular can be accounted for by the extreme difficulty of having the conditions so exactly the same as not to cause some slight variation in the speed.

Effect of Large Quantities of Nitrogen on the Reaction.

The following experiments may be quoted to show that the presence of nitrogen, even in large quantities, has very little effect on the reaction :—

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	258	269	656	..	..
129	210	245	596	20·9° C.	2·2
318	141	212	494	..	2·4
411	118	202	461	..	2·4
1236	63	175	379	..	1·4

Partial pressure of nitrogen = 129 mm.
Partial pressure of acetic acid = 12 mm.

Time in Minutes.	p_2.	p'.	P.	Temperature.	K′.
0	304	286	1025	24·8° C.	..
73	268·6	267·4	984	24·8° C.	2·4
158	237·3	251·7	937	24·8° C.	2·0
188	227·4	246·6	922	24·8° C.	2·1
223	218	242	908	24·8° C.	1·9
283	208	237	893	24·8° C.	1·7

Partial pressure of nitrogen = 435 mm
Partial pressure of acetic acid = 15 mm.

General Conclusions.

The general conclusions arrived at are :—

1. That acetaldehyde is oxidized directly to acetic acid, the action taking place between the aldehyde molecules and the free oxygen atoms present.

2. That, with certain modifications, the action can be said to proceed with a velocity proportional to the pressure of aldehyde and to the square root of the pressure of oxygen.

3. The two chief modifications to be remembered are: (*a*.) That at no time during the reaction has equilibrium been established between the oxygen atoms formed and the oxygen molecules re-formed, the result being that more oxygen atoms are available for combination than would be calculated from a state of equilibrium, and the extent of this excess depends on the percentage pressure of aldehyde. (*b*.) That it is possible that the collision between an oxygen molecule and an aldehyde molecule may result in the breaking-up of the oxygen molecule.

4. That the existence of a maximum pressure of oxygen above which the action does not proceed is doubtful. Any such maximum is certainly much higher than that indicated by Dr. Ewan. There was no cessation of action with a pressure of 850 mm. of oxygen.

5. That the action is greatly influenced by catalytic agents of every kind.

6. The effect of rise of temperature is to increase greatly the speed of the reaction, the value of the constant at 50° C. being four times as great as at 25° C.

Preliminary Note on the White Substance formed by the Interaction of Mercury, Aldehyde, and Oxygen.

Mention is made by Dr. Ewan of the fact that a mixture of aldehyde and oxygen attacks mercury, forming a white substance, and giving off an inflammable gas which is not absorbed by alkaline pyro-solution. There can be no doubt that the white substance is formed, and experiments were made to establish its nature and manner of formation.

No action was observed between the pure acetaldehyde and mercury.

On allowing oxygen to pass into the reaction-vessel, which had contained the mercury and aldehyde for three hours, the formation of the white substance was soon noted. In fifteen minutes an incrustation had formed on the surface of the mercury. After fifteen hours a considerable quantity of white substance was obtained.

If any inflammable gas unabsorbed by alkaline pyro-solution is formed, it is extremely small in quantity, and not at all as much as would be expected from the quantity of white substance formed.

In appearance and properties the white substance distinctly resembles mercurous acetate, and a considerable amount of evidence has been gained in support of the view that, as formed, it is mercurous acetate, an oxide of mercury being first formed by the action of the oxygen on the mercury, and this then attacked by the acetic acid.

The white substance carries small particles of mercury, which can be separated with very great difficulty.

ART. VIII.—*Studies on the Chemistry of the New Zealand Flora.*

By T. H. EASTERFIELD, Victoria College, Wellington.

[*Read before the Wellington Philosophical Society, 5th October, 1910.*]

PART IV.—THE CHEMISTRY OF THE PODOCARPI.

THE present paper summarizes, for the use of New Zealand readers, work which has been carried on for several years in the Victoria College laboratories on various species of New Zealand *Podocarpi*. The full details have in part already appeared in the "Transactions of the Chemical Society," and others will shortly be forwarded for publication in that journal. These details are of too technical a nature to be of interest to any except the highly trained specialist, who can readily refer to the journal in question, which is taken in the library of each of the University Colleges.

(1.) *The Miro* (Podocarpus ferrugineus).

The miro appears to be the only New Zealand member of the family which weeps drops of resin when the bark is incised (*Ueberwallungsharz*). The resin thus obtained is valued by bushmen for the treatment of cuts and sores. A quantity of this resin collected in Westland was steam-distilled, and the volatile oil resulting from this process was dried and distilled several times in contact with metallic sodium. The highly refractive colourless oil was proved by analysis to have the formula $C_{10}H_{16}$, and the boiling-point, specific gravity, specific rotation, and refractive index showed conclusively that the substance was a mixture of dextro- and laevo-rotary pinene.

The water in which the resin had been boiled was only faintly acid, and contained traces only of matter in solution.

The non-volatile portion of the resin was neutral in reaction, and underwent no hydrolysis when boiled with alcoholic potash; it therefore contains neither esters nor lactones. After drying it can be distilled without decomposition under reduced pressure (15–20 mm.). The distillate sets on cooling to a glassy mass which has hitherto resisted all attempts to make it crystallize. The substance has a characteristic smell, recalling that of cannabinol, and is easily soluble in all ordinary organic solvents. Analyses of different preparations agree with the formula $C_{13}H_{18}O$.

(2.) *The Kahikatea* (Podocarpus dacrydioides).

It is well known that large logs of white-pine are frequently flawed by heart-shakes filled to a greater or less extent with a hard white or yellowish deposit, which also saturates and hardens the woody tissue in the neighbourhood of the cracks. A quantity of this deposit was dissolved in alcohol and crystallized by the cautious addition of water until a permanent opalescence resulted. In a few hours the whole solution was filled with colourless crystals, which when completely purified melted at 192° C., showed a specific rotation of +136°, and upon analysis and titration gave numbers agreeing sharply with the formula $C_{17}H_{22}O_3$. This is the formula for podocarpic acid discovered by Oudemans ("Annalen der Chemie," 1873, vol. 170, p. 213) in the heart-resin of *Podocarpus cupressinus* var. *imbricatus* (a tree common on the mountains of Java at a height of 4,000 ft. and upwards), and not since recorded in any other plant. By the kindness of

Dr. Treub, Director of the Royal Botanical Gardens at Buitenzorg, I have been supplied with a sample of this resin, and have prepared podocarpic acid from it. The acid agreed in all physical constants with the acid from kahikatea; and the lower melting-point of podocarpic acid given by Oudemans (188°–189°) is probably due to the difference in the conditions under which the determination was carried out.

In the investigation of the miro and kahikatea I have been ably assisted by Miss A. I. Slowey, M.A.

(2A.) *The Rimu* (Dacrydium cupressinum): *a Correction.*

The close resemblance between the acids of red and white pine has caused Mr. Aston to re-examine the acid prepared from the former, which was previously described under the name "rimuic acid" (Trans. N.Z. Inst., 1903, vol. 36, p. 483). Careful comparison of the physical constants and titration values has shown that podocarpic and rimuic acid are identical, so that the latter name should be erased from chemical literature. At the same time it should be pointed out that the difference between the percentage composition of an acid of the formula $C_{16}H_{20}O_3$, ascribed to rimuic acid, and the formula for podocarpic acid ($C_{17}H_{22}O_3$) is so small (0·6 per cent. in the carbon and 0·3 per cent. in the hydrogen) that titration can alone settle the question of the correct formula. The titration values show with certainty that Oudeman's formula is the correct one.

It is not without interest that trees whose external characters have led to the nomenclature *Dacrydium cupressinum*, *Podocarpus cupressinus*, and *Podocarpus dacrydioides* should be characterized by containing the same acid, whilst this acid is absent in the other species of *Podocarpus* and *Dacrydium* which have hitherto received the attention of the chemist.

(3.) *The Matai* (Podocarpus spicatus).

(In conjunction with James Bee, M.A., M.Sc.)

In the matai (mai, or black-pine) heart-shakes are not nearly so common or so large as in the rimu and kahikatea. When they do occur, however, well-formed radiating groups of crystals may often be detected in the yellow deposit within the cracks. It was expected that this material would also be found to consist of podocarpic acid. The substance was found, however, to be rather sparingly soluble in cold alcohol, whereas podocarpic acid dissolves easily. From hot alcohol the substance separated on cooling in crystals containing alcohol of crystallization, melting at 77°–78°, and having the formula $C_{19}H_{20}O_{6},C_2H_6O$. After removing the alcohol of crystallization the compound melts at 119°, shows a specific rotation of +4·89°, crystallizes from 60 per cent. acetic acid in large prisms, and is intensely soluble in acetone, insoluble in light petroleum. The alcoholic solution is coloured green by the addition of an aqueous solution of ferric chloride. Upon distillation a strong smell of eugenol is produced. As regards chemical constitution, two of the oxygen atoms are present as hydroxy groups and two as methoxy groups; the remaining pair is present as a lactone group; so that the formula may be rewritten $C_{16}H_{12}(OH)_2(O\,CH_3)_2CO\,O-$. The compound yields well-characterized monacetyl, dibenzoyl, and sulphonic-acid derivatives. Matai resinolic acid, $C_{16}H_{13}(OH)_2(O\,CH_3)_2CO_2H$, has also been prepared; it crystallizes with 3 molecules of water of crystallization, and is reconverted to the lactone if boiled with water or by the action of cold dilute mineral acids.

Matai-resinol is isomeric with pino-resinol, the crystalline constituent of the exudation resins of *Pinus laricio* and *Picea vulgaris* isolated by Max Bamberger (Monatshefte, 1894, vol. 15, p. 505). Pino-resinol also contains two methoxy and two hydroxy groups, but experiments do not appear to have been made in order to ascertain if the substance is lactonic in character. Pino-resinol differs from matai-resinol in having a higher melting-point and in yielding a very sparingly soluble potassium-salt.

(4.) *The Totara* (Podocarpus totara).

No heart-resin can be observed in totara logs, but a crystalline "bloom" can often be detected on totara boards a few hours after leaving the planing-machine. To investigate this substance, 1 cwt. of totara sawdust was extracted with alcohol and the spirit removed by distillation. The residue was an amorphous mass easily soluble in organic solvents, but crystallizing with great difficulty from most menstrua. By spontaneous evaporation of the solution in light petroleum the substance is easily obtained in large crystals. The compound is neutral in reaction, and is not hydrolized by alcoholic potash; it distils under diminished pressure without decomposition. Analysis supports the formula $C_{18}H_{26}O$.

In the investigation of this substance I have received much help from Mr. George Bagley.

ART. IX.—*Further Experiments on the Influence of Artesian Water on the Hatching of Trout.*

By C. COLERIDGE FARR, D.Sc., and D. B. MACLEOD, M.A.

[*Read before the Philosophical Institute of Canterbury, 19th October, 1910.*]

THE experiments here described were carried out in conjunction with the authorities of the Canterbury Acclimatization Society at their hatchery in Christchurch, and our thanks are due to the Acclimatization Society for the facilities they have offered us, and to Mr. Charles Rides especially for the interest he has taken in arranging the eggs, &c., for us.

The work conducted last year (Trans. N.Z. Inst., vol. 42, 1909) showed conclusively that the artesian water of Christchurch was fatal to a large number of fish confined in close proximity to the outflow of the well, and of those fish which survived only a very small proportion escaped pop-eye. Both these effects disappear on aeration of the water, which was shown to contain an excess of nitrogen, a defect of oxygen, some carbon-dioxide, and radium-emanation in solution.

It seemed likely from the experiments carried on last year that the mortality amongst the eggs and also the development of "blue swelling" were troubles which were minimized by aeration, and to clear up these points, and, if possible, to throw some light on the particular factor producing these effects, the experiments here described were made.

The Acclimatization Society very kindly placed at our disposal for the experiments two sets of hatching-boxes, one containing five trays, with a fall from tray to tray, and the other eight trays, with a similar fall. In each of these thirteen boxes 2,000 "wild" brown-trout ova were placed under the conditions known from experience in the hatchery to give the best

hatching results. Reference to the paper already referred to will show that these conditions were entirely different from those adopted last year, when 7,500 eggs were placed in each of the five boxes of one of these sets, and the eggs were simply laid on the bottom of the box. On this occasion the 2,000 eggs were placed on a gauze tray at least an inch from the bottom, and the water circulated through the tray, flowing from the bottom upwards. It is no doubt entirely due to these better conditions that the death-rates to be given are so low compared with last year's, when the conditions were previously known to be such as would produce great mortality, both in the egg and yolk-sac stage.

An examination of the radio-activity of the water of the top boxes in each set revealed the fact that whereas the activity of one set was 126, the same as last year, and expressed in the same units, the activity of the top box of the other set was only 78. As this difference existed between the radio-activity of the two boxes, a very careful examination of the gas-content of the two boxes was made. The results appended are a mean of five determinations of each box, and in no single case did the result differ appreciably from the mean.

Box No.	Emanation.	Gas-content.	2,000 Brown Trout. Eggs.	2,000 Brown Trout. Blue Swelling.	2,500 Rainbow. Blue Swelling.
		Boxes on Right of Door.			
1	126	N .. 16·35	252	70	102
		O .. 4·30	(254)	(72)	
		CO_2 .. 2·60			
2	111	..	302	68	88
			(224)	(72)	(87)
3	95	..	167	41	73
4	83	..	214	33	71
5	69	N .. 15·35	184	29	58
		O .. 5·45	..	(28)	(57)
		CO_2 .. 2·53			
		Boxes in Front of Door.			
1	78	N .. 16·31	156	34	97
		O .. 4·76			
		CO_2 .. 2·37			
2	75	N .. 16·00	163	38	142
		O .. 5·15			
		CO_2 .. 2·45			
3	73	..	184	35	80
4	..	..	185	36	87
5	..	..	198	33	70
6	..	..	154	38	57
7	36	N .. 15·20	195	31	52
		O .. 6·35			
		CO_2 .. 2·43			
8	..	..	172	30	37

A glance at these figures will show that, while the two top boxes are practically identical in nitrogen-content, that supplying the set of five trays has a little less oxygen (0·46 c.c. per litre), but has an emanation content 1·6 times that of the other.

Under the headings "Eggs" and "Blue Swelling" are given the numbers of deaths as eggs, or in the yolk-sac stage due to blue swelling, as the case may be. The figures in brackets indicate the same quantities in check boxes occupying parallel positions to those in the same square. Only a few such parallel boxes were used in the one set of trays.

The last columns in each set are not strictly comparable. They refer to the same class of fry which were hatched from "pond" and not "wild" ova, and in the longer set of trays we had only a few eggs at the end of the hatching season to experiment with, and the results were raised to the 2,500 basis for comparison. The discussion of these figures in conjunction with last year's results show, we think, that both the death of eggs and also blue swelling decrease as the water becomes more aerated, and this seems to be more the case in the set of five boxes than in the set of eight. It may not be considered to be very marked as regards eggs in either set of the brown-trout ova, but it was very evident in the same set of boxes last year, when 7,500 eggs were hatched in each box. Taking the figures as they are, while it cannot be said there is any falling-off in the number of deaths in the eggs in the set of eight boxes, there is a slight falling-off in the set of five boxes, and a distinctly greater mortality on the whole, especially in the boxes nearest the well.

As regards blue swelling, whereas in both sets of rainbow fry, and in the set of five trays with the 2,000 brown trout, there is a marked falling-off from box to box, yet in the set of eight boxes it seems that the mortality, as with the eggs, is practically constant.

It would appear that, taken as a whole, the figures obtained last year and these indicate that both these troubles are due to want of aeration, though it cannot, of course, be denied that some eggs would die even though river-water perfectly aerated were used.

The hatching season is short, and the whole of the hatchery cannot, of course, be handed over to experiments of this kind, and hence the results are meagre, and conclusions as to the particular constituent in defect or excess which is the cause of the mortality must be drawn with caution.

If it be admitted that the mortality depends to some extent on the aeration, then we think it can only be due to defect of oxygen or excess of radium-emanation. Besides the improbability of so inert a gas as nitrogen affecting the fish, the very small percentage differences between the nitrogen-contents of the two top boxes would further reduce the probable effect of nitrogen.

At present it is practically impossible to decide between a defect of oxygen and an excess of radium-emanation. Both these tend to disappear as the water is aerated, so that the two cannot be well separated.

We hope we may be able to perform crucial experiments by confining goldfish in a limited supply of water containing sufficient radium-salts to produce the emanation in quantities comparable with that in the wells. By such means one of the two factors could be eliminated.

ART. X.—*Notes and Descriptions of New Zealand* Lepidoptera.

By E. MEYRICK, B.A., F.R.S., F.Z.S.

Communicated by G. V. Hudson, F.E.S.

PART I.

[*Read before the Wellington Philosophical Society, Wednesday, 6th July, 1910.*]

THESE notes are again principally based on material received from Mr. G. V. Hudson and Mr. A. Philpott, for whose kind assistance I am very grateful.

CARADRINIDAE.

Leucania epiastra n. sp.

♂♀. 40–44 mm. Head and thorax light greyish-ochreous, thorax with two pairs of fine oblique black lines or series of specks, prothorax with strong triangular crest. Antennae in ♂ moderately fasciculate-ciliated. Abdomen pale greyish-ochreous with fine black specks, densely hairy towards base. Anterior tarsi with two apical joints black. Forewings light-brownish, with scattered black specks, towards base and costa suffused with light greyish-ochreous; first line represented by two or three black dots, second line by a series on veins; two white dots longitudinally placed about lower angle of cell, connected by grey suffusion; a terminal series of black dots between veins: cilia light brownish-ochreous. Hindwings fuscous, paler and tinged with pale greyish-ochreous towards base; cilia whitish-ochreous, tips whitish.

Makara; bred in October from larvae feeding in flowering-stems of *Arundo conspicua* (R. M. Sunley): two specimens received, through Mr. Hudson.

HYDRIOMENIDAE.

Chloroclystis melochlora n. sp.

♂♀. 20–27 mm. Head green. Palpi 2¾, green. Antennae in ♂ with two series of filaments bearing long fascicles. Thorax green, patagia spotted with black. Abdomen green, more or less dotted with black. Forewings triangular, costa somewhat sinuate in middle, apex obtuse, termen bowed, oblique; green; striae represented by series of irregular black marks on veins and margins, partially edged with white posteriorly, but on anterior edge of median band anteriorly; median band broad, considerably narrowed towards dorsum, margins curved, posterior with a sinuation above middle more conspicuously marked with black and edged with white; a transverse-linear black discal mark; subterminal line fine, waved, white, anterior edge strongly marked with black above middle: cilia green, barred with black. Hindwings with termen rounded; ochreous-whitish more or less tinged with greenish; sometimes some blackish dots on veins on dorsal half; a waved subterminal line sometimes indicated by pale-greenish anterior margin: cilia whitish-greenish.

Otira River (Hudson); in December: three specimens. A handsome species, only comparable with *muscosata*, but with termen of forewings more

oblique, median band much narrower dorsally, termen of hindwings not crenate, all wings without grey suffusion.

Notoreas leucobathra n. sp.*

♀. 21–25 mm. Head and palpi yellowish mixed with blackish hairs. Thorax blackish, patagia light-yellowish with some black hairs. Abdomen black, sides suffused with yellow, segmental margins slenderly white. Forewings triangular, costa faintly sinuate, apex obtuse, termen rounded, rather oblique; grey, suffusedly irrorated with blackish, and much mixed with bronzy-yellowish, especially on veins; lines moderately thick, white, subbasal and first more slender, curved, median straight or somewhat angulated in middle, second slightly curved outwards on upper ⅔, sometimes rounded-angulated in middle, subterminal formed of a waved series of marks or reduced to a short mark from costa: cilia white, barred with grey mixed with blackish. Hindwings with termen rounded; colour and markings as in forewings, but lines sometimes pale ochreous-yellowish, subbasal and first absent, second more curved, subterminal forming a series of cloudy marks: cilia as in forewings.

Otira River (Hudson), in December; two specimens. This species, allied to the *mechanitis* and *paradelpha* group, is at once easily distinguished from the other species of that group by the cilia, which are barred with white and dark bars to the base, whilst in others the basal half is wholly dark; the markings are also different in detail.

Notoreas isoleuca Meyr.

After considerable study of this and allied forms I am disposed to reinstate it as a good species, distinct from *mechanitis*. It is a smaller and shorter-winged insect (20–22 mm.): blackish, with little or no yellowish admixture; the lines white, first curved, second angulated in middle, others slender and sometimes partially obsolete; cilia with basal half dark fuscous, outer half whitish obscurely barred with grey.

Arthur's Pass (4,600 ft.), Castle Hill (over 4,000 ft.), in January.

Notoreas mechanitis Meyr.

This species is somewhat larger than the preceding (22–25 mm.), largely suffused with golden-yellow, which extends both over ground-colour and markings, especially on median area and subterminal line; cilia with basal half grey or dark grey, outer half whitish without bars.

Arthur's Pass (3,100 ft.), in January. In my original description I wrongly included examples from the higher levels at Arthur's Pass which were really referable to the preceding; this error was the cause of the subsequent confusion, which I think is now cleared up.

Notoreas atmogramma n. sp.

♀. 25–27 mm. Head, palpi, and thorax black, mixed with whitish-ochreous-yellowish hairs and scales. Abdomen black, mixed on sides with whitish-yellow, segmental margins slenderly whitish. Forewings triangular, costa straight, apex obtuse, termen rounded, rather oblique; dark fuscous, with a few scattered pale-yellowish scales; lines cloudy, light-yellowish, subbasal, first (and second partially) whitish, first curved, median very indefinite, second angulated in middle, subterminal irregular: cilia white,

* *Dasyuris leucobathra.* See Addendum, p. 68.

basal half fuscous. Hindwings with termen rounded; colour and markings as in forewings, but basal area irrorated with pale yellowish, subbasal and first lines obsolete, second somewhat bent in middle: cilia as in forewings. Under-surface of all wings light ochreous-yellow; first and second lines indistinctly indicated by whitish suffusion; forewings with some incomplete cloudy blackish lines; hindwings with a blackish discal mark.

Mount Holdsworth, Tararua Range, north of Wellington, 4,000 ft. (Hudson); three specimens. Referred to by me previously (Trans. Ent. Soc. Lond., 1905, p. 221) as a geographical form of *mechanitis*; but I am now satisfied that it is specifically distinct. It is larger, more obscure, without the strong golden-yellow suffusion, and the hindwings are wholly yellow beneath except the black discal mark, whereas in *mechanitis* they are marked with strong black lines.

MONOCTENIADAE.

Dichromodes cynica n. sp.

♂. 17 mm. Head, palpi, thorax, and abdomen blackish-grey, slightly whitish-sprinkled, palpi $3\frac{1}{2}$. Antennal pectinations 6. Forewings triangular, costa faintly sinuate, apex rounded-obtuse, termen obliquely rounded; dark grey sprinkled with black and grey-whitish, veins partially suffused with yellow-ochreous irroration; lines obscurely indicated by whitish irroration, irregular, first somewhat sinuate, indented below middle, edged posteriorly with black irroration becoming broad towards costa, second slightly prominent near costa and dorsum, and with a moderate bidentate prominence in middle, edged anteriorly with black irroration also becoming broad towards costa, subterminal hardly traceable; a small blackish transverse discal mark before second line: cilia dark grey, slightly sprinkled with black and whitish. Hindwings with termen rounded; dark fuscous; a fine indistinct grey-whitish curved post-median line, sinuate inwards in middle: cilia dark fuscous.

Lyttelton (Hudson), in November; one specimen. I have compared it with the type of *niger* Butl., but the lines are differently formed. The New Zealand species of *Dichromodes* appear to be scarce; they are probably very inconspicuous, and escape notice.

CRAMBIDAE.

Crambus schedias n. sp.

♂. 28 mm. Head white, sides of crown and centre of face pale brownish-ochreous. Palpi 4, light brownish-ochreous, white above and towards base beneath. Antennal ciliations $\frac{3}{4}$. Thorax brownish-ochreous, with broad white central stripe. Abdomen pale whitish-ochreous. Forewings elongate, narrow, somewhat dilated posteriorly, apex obtuse, termen at first straight, little oblique, then rounded off; bronzy-ochreous, deeper in disc; a fine white line beneath costa on anterior half; a rather narrow straight white median streak from base to termen; a white line along dorsum from base to $\frac{1}{3}$, where it becomes broader and subdorsal, becoming obsolete about $\frac{2}{3}$; four cloudy white lines towards costa posteriorly between veins: cilia ochreous-whitish. Hindwings ochreous-grey-whitish; cilia whitish.

Wellington (Hudson), in March; one specimen. Nearest to *callirrhous*, but lighter-coloured, and without the more numerous, prolonged, and well-defined white interneural streaks of that species.

Crambus thrincodes n. sp.

♂. 29 mm. Head white. Palpi 4, dark fuscous, white above and towards base. Antennal ciliations ¼. Thorax white, patagia suffusedly mixed with brownish. Abdomen pale yellowish-ochreous. Forewings narrow, rather dilated posteriorly, costa gently arched, apex obtuse, termen slightly rounded, rather oblique; light ochreous-fuscous; a broad suffused white costal streak, containing three elongate blackish costal marks, first reaching from base to ⅖, second from middle to near ¾, third from ⅘ to near apex; first line indicated on white streak by posterior margin of fuscous irroration, sharply angulated beneath costa, in disc white, incurved, edged with irregularly triangular blackish patches, beneath this obsolete; a circular white discal spot edged with blackish and centred with a fuscous dot, placed in a white longitudinal streak which does not reach first or second lines; second line between costal streak and dorsum white, slender, dentate, preceded in disc by some dark-fuscous irroration: cilia light greyish-ochreous, base suffused with white. Hindwings whitish-ochreous-yellowish; a spot of grey suffusion on costa before apex; cilia whitish-ochreous.

Kaitoke, Wellington (Hudson); one specimen. A singularly distinct species, related to *flexuosellus* and *tuhualis*.

PYRAUSTIDAE.

Scoparia dryphactis n. sp.

♂. 30–31 mm. Head and thorax pale ochreous, shoulders suffused with dark fuscous. Palpi 2½, pale ochreous sprinkled with dark fuscous, whitish towards base beneath. Antennae pale ochreous, ciliations ⅓. Abdomen whitish-ochreous. Forewings very elongate-triangular, narrow at base, costa posteriorly gently arched, apex obtuse, termen slightly rounded, rather oblique; pale ochreous, tinged with brownish or mixed with light fuscous, especially towards termen, somewhat sprinkled with dark fuscous on veins; a moderately broad streak of dark-fuscous suffusion along costa throughout; a short ferruginous streak from base on fold, surrounded with dark-fuscous suffusion; lines cloudy, pale, edged with fuscous suffusion, first oblique, second somewhat curved, indented beneath costa; spots indicated by longitudinal patches of ferruginous suffusion, indistinctly outlined with dark fuscous: cilia whitish-ochreous mixed with light fuscous. Hindwings 1⅔, with long hairs in cell; whitish-ochreous tinged with grey: cilia pale whitish-ochreous, with greyish subbasal line.

Wellington (Philpott), in February; two specimens. A very distinct species, allied to the group of *cyameuta*.

CARPOSINIDAE.

Carposina amalodes n. sp.

♀. 15–16 mm. Head and thorax white. Palpi 2½, white, dark fuscous beneath and towards base. Abdomen grey-whitish. Forewings elongate, rather narrow, posteriorly gradually dilated, costa gently arched, apex obtuse, termen slightly rounded, rather strongly oblique; white; a small blackish mark on base of costa; a transverse ochreous-yellow line near base, marked with black at extremities; a light-grey blotch irrorated with dark grey extending along dorsum from beyond this to ¾, and reaching more than half across wing, containing a yellow-ochreous ridge of scales much marked with black at ⅓, and a yellow-ochreous spot in a white ring

at ½; a small blackish spot on costa beyond ⅓, preceded by a black subcostal dot sometimes marked with yellow-ochreous; five small spots of blackish irroration on costa posteriorly, and some suffused grey irroration beneath these; two indistinct ochreous-yellowish dots above middle of disc, and an undefined transverse yellowish streak in disc at ⅔, surrounded with white; a curved-angulated subterminal streak of blackish irroration, and some grey irroration towards termen: cilia white, indistinctly barred with grey irroration. Hindwings pale whitish-grey; cilia white.

Otira River (Hudson), in December; two specimens. Very similar to *contactella*, and at present I have only females of each; distinct, however, by the rather broader forewings, with termen less straight and somewhat less oblique, the black costal spot beyond ⅓ and preceding subcostal dot (both of which are absent in *contactella*), and the less-grey hindwings.

TORTRICIDAE.

Pyrgotis eudorana Meyr.

♂. 18 mm. Head and thorax reddish-ochreous-fuscous, thoracic crest ferruginous-ochreous. Antennal ciliations 1. Abdomen whitish-grey, anal tuft ochreous-whitish. Forewings rather elongate-triangular, costa gently arched, with moderate costal fold reaching ⅖, apex obtuse, termen slightly sinuate, somewhat oblique; fuscous-purplish indistinctly strigulated with dark grey; costal fold brownish-ochreous strigulated with grey; a triangular apical ochreous-orange patch, marked with some dark-fuscous strigulae between veins and on costa, its anterior edge straight, running from ⅗ of costa to tornus; central fascia indicated as an evenly broad band of darker suffusion preceding this: cilia reddish-ochreous-fuscous. Hindwings pale grey, apical half ochreous-whitish; cilia ochreous-whitish, on lower half of termen basally spotted with light grey.

Kaitoke, Wellington (Hudson), in December; one specimen. This species was described from a female only; I feel little hesitation in referring the above to it as the other sex.

Cnephasia microbathra n. sp.

♂. 18 mm. Head, palpi, and thorax dark fuscous. Antennal ciliations 3. Abdomen rather dark grey. Forewings elongate-triangular, costa gently arched, slightly sinuate in middle, without fold, apex obtuse, termen hardly sinuate, somewhat oblique; brown, closely strewn throughout with whitish-grey dots arranged in series; a very small dark reddish-fuscous basal patch suffused with blackish, outer edge slightly curved; extreme costal edge whitish-ochreous with a few dark-fuscous scales; central fascia faintly darker, posteriorly rounded-prominent above and below middle, and anteriorly with an indefinite projection below middle, on costa forming a semioval reddish-ochreous-brown spot with its costal edge blackish; a fuscous spot beneath costa towards apex: cilia light brownish-ochreous. Hindwings and cilia rather dark grey.

West Plains, Invercargill (Philpott), in September; one specimen. Though not conspicuous, this is a very distinct species.

EUCOSMIDAE.

Bactra xystrota n. sp.

♂. 15–16 mm. Head and thorax whitish-ochreous. Palpi nearly 4, pale greyish-ochreous, whitish towards base beneath. Antennal ciliations 1.

Abdomen grey, anal tuft whitish. Forewings elongate, rather narrow, posteriorly slightly dilated, costa gently arched, without fold, apex round-pointed, termen slightly sinuate, rather strongly oblique; pale ochreous slightly tinged with brownish, sometimes partially suffused with whitish on costal third, veins sometimes marked with fine fuscous lines, sometimes with a few scattered black scales; some dots of dark-fuscous scales on dorsum; an undefined median streak from base to apex more or less indicated by darker suffusion or fuscous irroration, a dark-fuscous discal dot on lower angle of cell: cilia pale ochreous. Hindwings grey; cilia whitish, with grey subbasal line.

Invercargill, on coast sandhills (Philpott), in January, two specimens.

GELECHIADAE.

Gelechia glaucoterma n. sp.

♂. 9–10 mm. Head ochreous-whitish, back and sides of crown suffused with grey. Palpi ochreous-whitish, terminal joint shorter than second. Antennae dark fuscous. Thorax dark grey mixed with blackish. Abdomen light grey, segments 4–6 somewhat blackish-mixed, segmental margins whitish. Forewings elongate, narrow, costa slightly arched, apex acute, termen extremely obliquely rounded; dark grey; an oblique bar of white suffusion from costa at $\frac{1}{6}$, reaching half across wing, accompanied with some whitish-ochreous scales, sometimes tending to extend along costa to base; an undefined patch of blackish suffusion in disc beyond this, representing first discal and plical stigmata, and a rather large roundish black spot representing second discal, with more or less whitish irroration between these and on margins of second discal; a white patch occupying apical fourth, mixed with dark grey or dark fuscous towards apex, anterior edge irregularly indented in middle: cilia whitish, with an interrupted fuscous subbasal line. Hindwings 1, grey-whitish, apex greyer; cilia whitish.

Invercargill, on coast sandhills (Philpott), in January; two specimens.

OECOPHORIDAE.

Borkhausenia paratrimma n. sp.

♂. 14–15 mm. Head and thorax ochreous-fulvous. Palpi and antennae dark grey, antennal ciliations 1. Abdomen grey. Forewings elongate, rather narrow, costa gently arched, apex round-pointed, termen very obliquely rounded; ochreous-fulvous, somewhat sprinkled with grey, towards all margins suffused with grey irroration; two oblique fasciae of grey irroration crossing plical and second discal stigmata, which are marked on them as indistinct cloudy darker dots: cilia ochreous-fulvous irrorated with grey. Hindwings and cilia grey.

Invercargill (Philpott); two specimens. A distinct though inconspicuous species, which may be regarded as an early form of the *siderodeta* group.

Borkhausenia nycteris Meyr.

♀. 17 mm. Head and thorax dark bronzy-fuscous, somewhat mixed with light ochreous. Palpi dark fuscous mixed with pale ochreous, second joint with erect projecting scales beneath. Abdomen dark brown, sides and margin of segments dark grey. Forewings bronzy-brown, base of scales dark fuscous, towards base of costa and in middle of disc mixed with yellow-ochreous; a yellow-ochreous blotch extending along basal $\frac{2}{5}$ of

dorsum, its extremities grey; stigmata black, plical obliquely before first discal, connected by a black mark with extremity of preceding dorsal blotch, and edged beneath by a white dot; an indistinct spot of whitish suffusion beneath costa towards base and a larger and more defined one on costa before middle; a white streak connecting second discal stigma with dorsum before tornus, preceded on dorsum by a black mark; apical third suffused with yellow-ochreous, including a subterminal shade of dark brown and blackish irroration sharply indented beneath costa, partially edged with whitish suffusion, especially towards costa: cilia light yellow-ochreous, towards apex and tornus suffused with dark grey, beneath tornus with a white mark. Hindwings grey; cilia grey, with darker subbasal line.

This handsomely variegated female was taken by Mr. Hudson *in cop.* with a normal dark-fuscous male, to which it is superficially very dissimilar; both sexes, however, agree in the peculiar erect projecting scales of the second joint of palpi (not noticed in my original description), and could be separated from all others known to me by this character alone. My original description is stated as including the female, but I think this must be an error; at any rate, all the specimens in my series are males. Taken at the Otira River by Mr. Hudson; previously from Wellington and Invercargill.

Borkhausenia plagiatella Walk.

Tinea plagiatella Walk., Cat., vol. 28, p. 485; *Gelechia contextella*, *ib.*, vol. 29, p. 656.

♂♀. 15–17 mm. Head ochreous-whitish, face sometimes yellower. Palpi white, second joint dark fuscous except towards apex, terminal joint sometimes sprinkled with dark fuscous in middle. Antennal ciliations almost 1. Thorax whitish-ochreous sometimes yellowish-tinged, shoulders dark fuscous, sometimes dorsally suffused with fuscous or marked with dark fuscous. Abdomen grey. Forewings elongate, rather narrow, costa gently arched, apex round-pointed, termen very obliquely rounded; white; markings brownish-ochreous irrorated with blackish or dark fuscous: a fascia from base of costa above fold to plical stigma: costal blotches at $\frac{1}{4}$, middle, and $\frac{3}{4}$, last sending a curved dark-fuscous line to tornus; discal stigmata black, second crescentic, filled with ochreous-yellowish beneath, plical represented by an oblique black mark above which is some ochreous-yellowish suffusion; a dorsal blotch of ochreous-yellowish suffusion towards base; a triangular patch of ochreous suffusion occupying middle of dorsal area, irrorated with blackish posteriorly; a fascia of ochreous-yellowish suffusion variably sprinkled with dark fuscous running from middle costal blotch to tornus; an irregular apical spot more or less produced along termen: cilia whitish-yellowish, with apical and tornal blotches of dark-fuscous irroration. Hindwings and cilia grey.

Wellington, Otira River (Hudson), Nelson, in December and January; eight specimens. Distinguished from its nearest allies, *contextella* Meyr. and *hemimochla*, by the well-marked partial yellowish suffusion of forewings and grey hindwings.

Borkhausenia contextella Meyr.

Oecophora contextella Meyr. (*nec* Walk.), Trans. N.Z. Inst., 1883, p. 37

♂♀. 14–17 mm. Hindwings and cilia should be described as grey-whitish. This species is, so far as I can determine from an examination

of the type, not the true *contextella* Walk., which, as shown above, is a synonym of *plagiatella*, but under these circumstances may still be known as *contextella* Meyr.; the absence of the yellow dorsal blotch and other yellow suffusion, and the grey-whitish hindwings, distinguish it from *plagiatella*. The geographical range is apparently quite distinct—viz., from Christchurch to Invercargill.

Borkhausenia amnopis n. sp.

♀. 16–17 mm. Head whitish-ochreous, sides and back of crown sprinkled with fuscous. Palpi moderate, whitish-ochreous irrorated with dark fuscous, apex of joints ochreous-whitish. Thorax fuscous irrorated with ochreous-whitish, sometimes with dorsal area whitish-ochreous. Abdomen brownish, segmental margins whitish-ochreous. Forewings elongate costa gently arched, apex round-pointed, termen almost straight, rather strongly oblique: whitish-ochreous irrorated with fuscous; an undefined band of brown suffusion and dark-fuscous irroration from base of costa to an oblique raised black mark representing plical stigma, posteriorly whitish-edged; discal stigmata formed of black irroration, second rather large, subannular; a subtriangular spot of black irroration on dorsum at $\frac{2}{5}$, posteriorly whitish-edged; a fascia of brown suffusion irrorated with dark fuscous running from $\frac{2}{3}$ of costa across second discal stigma to tornus, edged with whitish anteriorly on lower half; a subterminal line of black irroration edged anteriorly with whitish suffusion, indented beneath costa: cilia whitish-ochreous beneath apex and on tornus with patches of fuscous and dark-fuscous irroration. Hindwings grey; cilia light grey, with darker subbasal shade.

Invercargill (Philpott); two specimens. Somewhat intermediate between the groups of *griseata* and *plagiatella*. Though obscure and liable to be passed over, it is not very close to any other species. The black subterminal line, more sharply indented than usual, is a noticeable character.

Borkhausenia asphaltis n. sp.

♂. 22 mm. Head, palpi, and thorax purplish-grey; antennae pubescent-ciliated ($1\frac{1}{2}$). Abdomen grey, segments dorsally dark brown except on margins. Forewings elongate, rather narrow, slightly dilated posteriorly, costa gently arched, apex obtuse, termen very obliquely rounded; grey, with scattered purplish scales, indistinctly suffused with dark-fuscous irroration towards base and anterior half of costa and on a triangular tornal patch; some scattered dark-fuscous scales towards dorsum; stigmata blackish, plical hardly before first discal; traces of a curved indented cloudy darker posterior line: cilia grey tinged with purple, on costa paler and suffused with rosy-purplish. Hindwings grey, darker posteriorly; cilia grey, tips grey-whitish.

One specimen received from Mr. Philpott; exact locality unknown. It is allied to *scholaea*, but distinct.

Trachypepla ingenua n. sp.

♂. 18 mm. Head rather dark fuscous irrorated with whitish. Palpi dark fuscous, second joint sprinkled with white towards apex, terminal joint white with two bands of dark-fuscous irroration. Antennal ciliations $1\frac{1}{2}$. Thorax dark fuscous. Abdomen brownish finely irrorated with whitish, segmental margins whitish-grey. Forewings elongate, rather narrow, costa moderately arched, apex obtuse, termen very obliquely rounded; white;

a dark purplish-fuscous basal patch occupying $\frac{2}{5}$ of wing, outer edge straight, mixed with chestnut-brown towards edge from above middle to near dorsum; some scattered grey scales in disc beyond this; an irregular-triangular dark purplish-fuscous blotch on costa beyond middle, reaching more than half across wing, posterior edge excavated beneath costa, its lower portion mixed with chestnut-brown; a ring of dark-fuscous irroration preceding apex of this blotch in disc, and partly limited by it: a narrow transverse suffused grey patch in disc following this; a curved cloudy line of dark-fuscous irroration from $\frac{4}{5}$ of costa to tornus, forming a triangular dark-fuscous spot on costa, and indented beneath this: cilia whitish, round apex tinged with grey and somewhat sprinkled with dark fuscous. Hindwings light grey; cilia whitish.

Otira River (Hudson), in December; one specimen. Nearest *nyctopis*, but very distinct.

Trachypepla amorbas n. sp.

♀. 19 mm. Head, palpi, and thorax dark fuscous irrorated with whitish, second joint of palpi beneath with rather long dense projecting hair-scales. Abdomen dark brown, segmental margins whitish. Forewings elongate, rather narrow, costa slightly arched, apex rounded-obtuse, termen obliquely rounded: dark fuscous, finely irrorated with whitish on basal third, costal patches at $\frac{1}{2}$ and $\frac{2}{3}$, and two or three small costal spots posteriorly, and slightly elsewhere; stigmata forming small tufts, discal edged above with brownish-ochreous, plical beneath first discal, second discal united with a similar tuft beneath it and both edged posteriorly by a whitish line: an indistinct curved subterminal line indicated by whitish irroration: cilia fuscous, with dark-fuscous subbasal shade. Hindwings dark fuscous; cilia as in forewings.

Invercargill (Philpott); one specimen. This species is distinguishable structurally from the rest of the genus by the peculiar scaling of palpi, but it does not seem necessary to separate it.

Trachypepla lichenodes Meyr.

♂♀. 14–15 mm. Antennal ciliations of ♂ 4. Light-yellowish markings of forewings variable in development; anterior dorsal blotch sometimes wholly absent: subterminal line sometimes reduced to a series of dots, sometimes continuous and enlarged into a blotch on costa.

Otira River (Hudson); three specimens.

GRACILARIADAE.

Gracilaria elaeas n. sp.

♂♀. 12–14 mm. Head and thorax light-brownish, more or less mixed or suffused with whitish. Palpi rather stout, whitish, terminal joint suffused externally with dark grey. Antennae whitish ringed with dark fuscous. Abdomen grey. Forewings very narrow, elongate-lanceolate; brownish-ochreous with a strong brassy-yellowish gloss; in one specimen the wing is suffused with deep purple, except a moderate dorsal streak and costal edge; more or less numerous variable deep purple-fuscous dots arranged along fold, and in an irregular longitudinal series above middle; some dark purple-fuscous irroration towards apex: cilia brownish-ochreous, on an apical bar sprinkled with dark fuscous. Hindwings and cilia grey.

Castle Hill; bred in February from larvae feeding in January between spun leaves or shoots of *Coriaria ruscifolia, thymifolia*, and *angustissima*;

twelve specimens. I have now recognized that this insect, which I formerly recorded as identical with *linearis*, is a good and distinct species, easily separated by the grey hindwings, and also differing in several other respects. It is interesting to note that the food-plant *Coriaria* is highly poisonous.

Gracilaria linearis Butl.

♂♀. 13–15 mm. Head and thorax brownish, sometimes with lilac reflections, face whitish-ochreous. Palpi rather stout, ochreous-whitish, terminal joint suffused externally with dark fuscous. Antennae whitish ringed with dark fuscous. Abdomen pale whitish-ochreous. Forewings very narrow, elongate-lanceolate; ochreous-brownish, sometimes with purple reflections, more or less strewn irregularly with small scattered dark purplish-fuscous dots or strigulae; costal area sometimes tinged with brassy-yellowish anteriorly; a triangular ante-median costal patch slightly paler, edged with several variable dark purplish-fuscous dots or marks; some dark-fuscous irroration towards apex: cilia whitish-ochreous, round apex more or less brownish-tinged and irrorated with blackish. Hindwings and cilia ochreous-whitish.

Wellington, Otira River, in January; four specimens. Immediately known by the ochreous-whitish hindwings, and always perceptible triangular costal patch. Butler's types include one example of each species, but his description mentions the "white" hindwings, which fixes the identification. As recorded above, the larva which I described as belonging to this species was really *elaeas*; the actual larva is unknown.

PLUTELLIDAE.

Simaethis colpota n. sp.

♀. 13 mm. Head and thorax dark bronzy-fuscous sprinkled with whitish. Palpi with whorls of dark-fuscous scales tipped with white, second joint with rough projecting scales, whitish towards base beneath. Antennae black ringed with white. Abdomen blackish-fuscous, segmental margins brownish. Forewings elongate, rather dilated posteriorly, costa slightly arched, apex obtuse, termen bowed, rather oblique; dark bronzy-fuscous, basal and terminal areas finely sprinkled with whitish; two parallel rather curved irregular transverse lines of whitish irroration about $\frac{2}{5}$; a transverse line of whitish irroration from a white mark on costa at $\frac{3}{5}$, its upper $\frac{2}{3}$ forming a strong irregular curve outwards, thence right-angled to dorsum at $\frac{3}{5}$; a transverse linear mark of whitish irroration terminated beneath by a white dot lying within this curve and almost touching it at both ends; a thick subterminal shade of whitish irroration, somewhat interrupted above middle: cilia dark fuscous with some whitish points, beneath apex and above tornus with white apical patches. Hindwings dark grey, terminal half blackish; two parallel lines of whitish irroration towards termen on lower half, posterior less marked: cilia dark fuscous with blackish subbasal shade, beyond this suffused with whitish on lower half of termen.

West Plains, Invercargill (Philpott), in March; one specimen. Allied to *combinatana*, but very distinct by the discal mark and form of second line.

Glyphipteryx bactrias n. sp.

♂. 14–15 mm. Head and thorax light ochreous-bronzy. Palpi whitish-ochreous, second joint with appressed scales, with two blackish rings towards

apex, terminal joint with blackish anterior line. Antennae dark fuscous. Abdomen blackish-grey, apex whitish. Forewings elongate, rather narrow, costa gently arched, apex produced into a long slender acute projection, termen beneath this sinuate-indented, thence very obliquely rounded; ochreous-bronzy; a moderate white median longitudinal streak from base to termen beneath apex, terminated by a shining leaden-metallic mark extending along median portion of termen: cilia greyish, base ochreous-bronzy, on costa mixed with dark fuscous, with three whitish wedge-shaped marks, round apical projection dark fuscous, with two silvery-whitish dots on its lower edge near base. Hindwings and cilia blackish-grey.

Invercargill, on coast sandhills (Philpott), in January; two specimens. Very distinct. The form of forewings is unique in the genus.

TINEIDAE.

Tinea astraea n. sp.

♀. 12 mm. Head dark fuscous mixed with white hairs. Palpi white, bristles dark fuscous, terminal joint dark fuscous except apex. Antennae blackish lined with white. Thorax blackish, margins of patagia marked with fine white lines. Abdomen bronzy-fuscous, segmental margins white on sides. Forewings elongate, rather narrow, costa gently arched, apex obtuse, termen extremely obliquely rounded; all veins separate; blackish; apical $\frac{2}{5}$ bronzy-fuscous; five fine white longitudinal lines from base in disc, second and third reaching to near middle, others shorter; two very short white marks on costa near base; pairs of oblique white streaks from costa at $\frac{1}{4}$ and middle, reaching half across wing; pairs of short broken ochreous-whitish streaks from dorsum at $\frac{1}{4}$ and $\frac{1}{2}$; posterior area with four or five less-oblique diminishing white streaks from costa, and three iridescent silvery-whitish from tornus and termen, nearly meeting in disc: cilia whitish-bronzy, with a black basal line interrupted by silvery dots beneath apex and in middle of termen, and posterior half suffused with dark fuscous. Hindwings grey, with purplish reflections; cilia grey, with dark-grey basal line.

West Plains, Invercargill (Philpott), in December; one specimen. A very remarkable insect, superficially quite unlike any other of the genus. The general type of marking suggests a *Glyphipteryx* (to which, of course, there is structurally no relationship), and I was disposed to suspect mimicry, but there is no close similarity to any New Zealand species known to me, nor is it a likely explanation in this instance; it is an interesting case, deserving of special investigation.

ADDENDUM.

Mr. Hudson has since informed me that the male of the species described above as *Notoreas leucobathra* has not pectinated antennae; it should therefore be referred to the genus *Dasyuris*.

The following three species, forwarded to me by Mr. Hudson, and captured in the first instance by Mr R. M. Sunley, can only be regarded as accidental introductions. In no case are the circumstances sufficiently known to make their occurrence comprehensible, and further investigations should be made to explain this. All three are alike unexpected, but where so much is unknown all things are possible.

GELECHIADAE.

Symmoca quadripuncta Haw.: Meyr., Handb. Brit. Lep., p. 611.

Nelson, in February (Sunley). A British species, widely distributed in the European region; not known from Australia.

OECOPHORIDAE.

Phloeopola confusella Walk.: Meyr., Proc. Linn. Soc. N.S.W., 1883, p. 354.

Nelson, a series (Sunley); Wellington, one specimen (Hudson). Common in New South Wales and Victoria, on trunks of *Eucalyptus*. I suspect the larva feeds in the bark. If this is so, the species might have been introduced with trees, but I should not expect to find it on saplings such as would be transplanted.

TINEIDAE.

Opogona comptella Walk.: Meyr., Proc. Linn. Soc. N.S.W., 1897, p. 416.

Nelson, in February (Sunley). Common in south-east Australia. Its larval habits are unknown, but the larvae of other species of the genus feed in dead woody fibre, in such varied situations as the stems of plants and the nests of Termites (white ants).

PART II.

[*Read before the Wellington Philosophical Society, 5th October, 1910.*]

For the specimens here described I am principally indebted to my valued correspondents Messrs. G. V. Hudson, A. Philpott, and R. M. Sunley, but have also discovered one or two overlooked species from my own collection.

CARADRINIDAE.

Dasygaster Gn.

This genus, allied to *Leucania*, is recognisable by the abdomen, which appears unusually thick from being expanded at the sides with fringes of dense hair, longer in ♂; it has a dorsal crest on basal segment. The genus is characteristic of Australia, and includes half a dozen species, of which one has now been found in New Zealand.

Dasygaster hollandiae Gn.

Dasygaster hollandiae Gn., Noct., vol. 1, p. 201; Hamps. Cat., vol. 5, p. 476. *D. leucanioides*, *ib.*, p. 202. *Graphiphora facilis* Walk., Cat., vol. 11, p. 745.

One specimen received from Mr. A. Philpott, taken at Waipori in January, 1889. The species is common in south-east Australia and Tasmania, and is doubtless a recent immigrant to New Zealand, very possibly accidentally introduced by man. I should add that the specimen has lost its abdomen, but I showed it to Sir George Hampson, and we are agreed as to its identity.

Leucania lissoxyla n. sp.

♂. 38 mm. Head light brown. Antennal shaft grey, becoming whitish towards base. pectinations *a* 4, *b* 3, terminating bristles minute. Thorax clothed with hairs, pale ochreous, more brownish anteriorly. Abdomen whitish-ochreous. Forewings elongate-triangular, apex rounded-obtuse, termen rounded, rather oblique; light brown; vein 1*b*, upper and lower margins of cell. and veins 2–4, 6–8, and apical third of vein 5 marked with lines of mixed blackish and whitish scales; faint streaks of pale-ochreous suffusion beneath cell and between veins 5 and 6: cilia pale ochreous, tinged with brownish towards base, tips whitish. Hindwings grey: cilia whitish-ochreous, tips whitish.

Mount Arthur tableland, 4,000 ft., in February (Hudson); one specimen. but Mr. Hudson has a second (♀) from same locality. Closely allied to *unica* and *toroneura*, but these three species are undoubtedly distinct, the structure of antennae in ♂ being different in each—viz., *unica*, pectinations *a* 2, *b* 1½, terminating cilia long, shaft ochreous-whitish; *toroneura*, pectinations *a* 3, *b* 2, terminating cilia moderate, shaft wholly white: *lissoxyla*. as described above.

Hyssia Gn.

I think this genus may be adopted as defined in Hampson's Catalogue, vol. 5, p. 278.

Hyssia inconstans Butl.

One female specimen received from Mr. A. Philpott, taken at Wellington in November. I have carefully compared it with the original type, and it is undoubtedly identical, and a good species. The second example (♂), however. referred to by Sir G. Hampson is in my judgment certainly only a male of *moderata*, and therefore the male characters assigned by him must be disregarded, and the true male remains to be discovered. The species appears to be scarce, but the group is so difficult. owing to the similarity of the species, that it may be overlooked.

Hyssia falsidica n. sp.

♀. 43 mm. Head whitish mixed with grey and blackish. Thorax grey mixed with whitish. Abdomen ochreous-grey-whitish. Forewings rather elongate-triangular, apex obtuse, termen slightly waved, obliquely rounded; fuscous-grey, mostly overlaid with white suffusion; subbasal line cloudy, dark fuscous, not reaching dorsum: first and second lines indistinctly margined with dark-fuscous irroration, first slightly curved. second waved, strongly curved outwards on upper ⅔; median shade of dark-fuscous irroration, bent near costa; orbicular-suboval, whitish, edged laterally with dark fuscous; reniform whitish, lower third fuscous-grey edged with whitish: anterior edge of subterminal line formed by a waved shade of dark-fuscous irroration. Hindwings fuscous.

Mount Arthur tableland, in February (Hudson); one specimen, in rather poor condition. Mr. Hudson possesses others, also poor, but the species seems sufficiently distinct.

Hydriomenidae.

Tatosoma Butl.

I am indebted to Mr. A. Philpott for calling my attention to the fact that two (or, as I find on examination, three) species have been confused

by me under the name of *agrionata*. These are now characterized below as follows; besides these, *lestevata* Walk., *timora* Meyr., and *lopia* Philp. are good species, making six altogether.

Tatosoma agrionata Walk.

Cidaria agrionata Walk., Cat., p. 1417. *C. inclinataria*, *ib.*, p. 1418. *Sauris mistata* Feld., Reis. Nov., pl. 131, p. 12.

This and the next species are extremely similar in colour and markings, but in *agrionata* the black markings on the striae of forewings are more strongly developed, especially on the subterminal line, where they form strong dashes, and above dorsum towards base; the forewings are also somewhat less elongate; an immediate distinction is furnished by the lobe of the hindwings in ♂, which is nearly twice as large as in *tipulata*, reaching from the base to nearly the middle of the wing in length.

I have this species from Christchurch, and Mr. Philpott sends it from Wallacetown.

Tatosoma tipulata Walk.

Cidaria tipulata Walk., Cat., p. 1417. *C. collectaria*, *ib.*, p. 1419. *Tatosoma agrionata* Huds., N.Z. Moths, 40, pl. 6, pp. 26, 27.

Forewings more elongate than in *agrionata*, less marked with black; hindwings in ♂ with lobe not exceeding ¼ of hindwings in length; abdomen of ♂ more elongate than in *agrionata*, but less so than in *timora*.

I have examples from Wellington and Nelson, and Mr. Philpott sends it also from Wallacetown.

Tatosoma transitaria Walk.

Cidaria transitaria Walk., Cat., p. 1419.

This is a distinct species, of which both sexes are represented in the British Museum collection, but otherwise not known to me; somewhat smaller than the two preceding, forewings duller, more grey-green, striae more obscure, with a characteristic distinct cloudy small whitish spot at lower extremity of transverse vein, hindwings smaller, rather dark grey, lobe in ♂ hardly larger than in *tipulata*.

Hydriomena lithurga n. sp.

♂. 25 mm. Head and thorax pale greyish-ochreous mixed with whitish, transversely barred with blackish-grey suffusion. Palpi 1½, blackish-grey, lower longitudinal half whitish. Antennae somewhat stout, shortly ciliated (¾). Abdomen pale greyish-ochreous, mixed on sides with dark grey and whitish, segmental margins white preceded by a black mark on each side of back. Forewings triangular, costa rather strongly arched towards apex, apex obtuse, termen rather obliquely rounded, crenate; pale greyish-ochreous, marked with indistinct waved striae of grey irroration becoming blackish on costa; margin of a small basal patch indicated on lower half by a blackish stria edged with white posteriorly; median band formed by two fasciae of several rather irregular suffused grey striae each, well marked except beneath costa, margins marked with black edged exteriorly with white except near costa, anterior margin twice sinuate, posterior with median third forming a rather strong subtriangular obliquely bilobate prominence; a transverse-linear black slightly whitish-edged discal dot on anterior of these fasciae; subterminal line of ground-colour, slender, strongly waved,

preceded by some grey suffusion towards dorsum and above middle, and cut by an oblique dark-grey streak from apex marked with blackish; a fine black terminal line: cilia whitish with two grey shades, with undefined dark-grey bars. Hindwings with termen rounded, crenate; grey-whitish, median band and subterminal line indicated by faint grey striae obsolete towards costa; a blackish-grey linear discal dot, cilia as in forewings, but dark markings nearly obsolete round apex.

One specimen received from Mr. R. M. Sunley, reared from pupa in loose cocoon beaten from *Muehlenbeckia*, Makara Beach, in November.

Xanthorhoe cedrinodes n. sp.

♂♀. 40 mm. Head and thorax dark grey mixed with brown-reddish. Antennal pectinations in ♂ *a* 2, *b* 1½. Abdomen grey. Forewings triangular, costa moderately arched towards apex, apex obtuse, termen waved, slightly rounded, rather oblique; reddish-fuscous, more or less sprinkled with black, tending to form curved waved transverse striae; costa marked irregularly with black; a curved band of several pale whitish-ochreous striae separating basal patch and median band, former edged with blackish and both slightly with white; median band broad, variably marked with black on edges and veins, middle third of posterior edge forming a moderate obtuse double prominence, partially finely edged with white posteriorly; beyond this a band of two or three cloudy pale whitish-ochreous striae, veins on this marked with black; subterminal line slender, waved, indistinct, pale whitish-ochreous; a black terminal line marked with ochreous-whitish dots on veins: cilia dark fuscous mixed with brown-reddish and whitish. Hindwings with termen somewhat rounded, crenate; pale rosy-greyish-ochreous, with traces of faint grey striae; posterior edge of median band more marked, angulated in middle, blackish-sprinkled towards dorsum; some reddish-fuscous suffusion along termen: a black terminal line: cilia reddish-fuscous mixed with ochreous-whitish and dark grey.

Mount Arthur tableland, 4,200 ft., on *Veronica* blossoms at night, in February (Hudson); two specimens.

Xanthorhoe practica n. sp.

♂. 24 mm. Head, thorax, and abdomen fuscous-whitish mixed with black and brown-reddish. Antennal pectinations *a* 7, *b* 6. Forewings triangular, costa moderately arched posteriorly, apex obtuse, termen slightly waved, somewhat bowed, oblique; light ochreous-grey sprinkled with dark fuscous; basal patch mixed with brown-reddish and white, with several blackish striae, outer edge slightly curved, separated from median band by a narrow whitish fascia; median band moderately broad, grey edged with two fasciae of three black striae each with their interspaces suffused with brown-reddish, first hardly curved, second somewhat irregular, nearly straight; a minute black discal dot; a fascia of two or three whitish striae following median band; subterminal line slender, waved, whitish, anteriorly dark-edged, and a similar stria near before termen; a blackish terminal line: cilia grey-whitish mixed with brown-reddish and obscurely barred with dark fuscous (imperfect). Hindwings with termen hardly waved, rounded; pale grey mixed with whitish, with waved grey striae, towards dorsum more distinctly striated with blackish and tinged with brown-reddish, with two distinct white striae beyond middle; a blackish terminal line: cilia whitish sprinkled with dark fuscous (imperfect).

Motueka, in January (Hudson); one specimen.

Xanthorhoe prymnaea n. sp.

♂♀. 32–35 mm. Head and thorax yellow-ochreous, shoulders mixed with ferruginous and dark fuscous. Antennal pectinations in ♂ *a* 6, *b* 4. Abdomen ochreous-yellowish. Forewings triangular, costa posteriorly moderately arched, apex obtuse, termen waved, rounded, oblique; ochreous-yellow; a small basal patch formed by three or four more or less marked strongly curved red-brown striae, marked with black on costa; median band enclosed by fasciae formed of one inner and two confluent outer rather waved dark red-brown striae marked with black on costa and on edges of band, sometimes connected below middle, anterior fascia narrow, somewhat irregularly curved, posterior moderately broad, dark and strongly marked posteriorly and somewhat edged with whitish suffusion, median third forming a broad obtuse double prominence, these fasciae in ♀ little marked except on edges of band; a black discal dot between these fasciae, space round it somewhat whitish-tinged, terminal area more or less tinged or striated with red-brown, including a slender waved white subterminal line edged anteriorly with fuscous suffusion, with an oblique subapical patch of dark suffusion: cilia crimson-fuscous, outer half barred with dark fuscous alternating with paler suffusion. Hindwings with termen rounded; ochreous-yellow; a small linear dark-grey discal dot; traces of two or three short grey strigae on dorsum; a fine dark-fuscous terminal line: cilia crimson-grey, indistinctly darker-barred.

Mount Arthur tableland, common in limestone valleys, 3,600–4,200 ft., in February (Hudson): five specimens.

PTEROPHORIDAE.

Platyptilia epotis Meyr.

Mr. Hudson sends a ♂ and ♀, taken in a swamp on the Mount Arthur tableland in February. These are more ochreous and less white than the type, with apical oblique streak less marked and in one specimen nearly obsolescent, but are certainly this species. At first sight they much resemble *lithoxesta*, but may be easily distinguished by the patch of white on costal cilia towards apex, and the black mark at base of terminal cilia on lower angle of first segment, and also in same position on first segment of hindwings. It hardly seems natural to separate the two species generically, but *epotis* shows slight traces of black scales in dorsal cilia of hindwings, whilst *lithoxesta* certainly has none.

TORTRICIDAE.

Epichorista emphanes Meyr.

♂. 13 mm. Antennal ciliations 1½. Forewings without costal fold; deep ferruginous, crossed by numerous oblique irregular series of very small subconfluent purplish-leaden-grey spots, without defined markings, but central fascia and costal patch sometimes indicated on costa. Hindwings blackish.

Mount Arthur tableland, 4,200 ft., in February; two ♂, one ♀, sent by Mr. Hudson as probably sexes of same species, which is doubtless correct; the ♂ differs considerably in appearance from the ♀, and has not been previously described.

Harmologa achrosta Meyr.

♂. 12–16 mm. Antennal ciliations 1. Forewings with costal fold moderate, extending from base to about middle, termen slightly rounded; dark fuscous, variably strewn with scattered ferruginous-yellowish hair-scales; basal patch, moderate central fascia, a narrow fascia from ¾ of costa to tornus, and some streaks posteriorly formed by darker strigulation, space between these somewhat leaden-tinged, but all very indistinct and sometimes obsolete even in fine specimens. Hindwings dark fuscous or blackish.

I describe four fresh specimens from Mount Arthur tableland, 4,200 ft., in February (Hudson); also, the insect lately described by me under the name of *epicura* from Castle Hill, 3,000 ft., in January, is now seen to be the same species, a lighter-coloured example.

Harmologa pontifica n. sp.

♂. 21 mm. Head, palpi, and thorax dark grey, forehead with a whitish transverse line. Antennal ciliations 1½. Abdomen dark grey, anal tuft pale greyish-ochreous. Forewings suboblong, costa moderately arched, with moderate fold extending from base to beyond ⅓, apex obtuse, termen slightly rounded, little oblique; greyish, with ashy-purplish reflections, irregularly sprinkled with dark fuscous and a few whitish scales; costal fold dark fuscous; outer edge of basal patch indicated on lower half by an erect fasciaform blackish mark from dorsum before middle; central fascia narrow, from before middle of costa to beyond middle of dorsum, blackish, mixed with ferruginous-reddish in disc; a blackish discal dot at ⅔; a small blackish spot on costa beyond central fascia; costal patch narrow, formed of three confluent blackish spots; a transverse irregular blackish streak from near this to tornus; some irregular blackish markings before lower half of termen: cilia grey mixed with blackish. Hindwings grey, becoming darker posteriorly; cilia grey-whitish, with grey subbasal line.

Mount Arthur tableland, 4,200 ft., in February (Hudson); one specimen.

Tortrix indigestana Meyr.

Two specimens reared from larvae feeding on *Pimelea laevigata*, Makara Beach, in October and November (Sunley). I had previously only one specimen from New Zealand, but the species is common in Australia, where it has been bred from *Hibbertia linearis*. The genus *Pimelea* is, however, common and characteristic in both regions.

Cnephasia holorphna n. sp.

♂. 18 mm. Head fuscous mixed with whitish-ochreous. Palpi 2½, clothed with very long rough projecting scales, whitish-ochreous sprinkled with fuscous. Antennal ciliations bifasciculate, 2½. Thorax fuscous, sprinkled and edged with whitish-ochreous. Abdomen fuscous, segmental margins and anal tuft whitish-ochreous. Forewings suboblong, costa gently arched, with moderate fold extending from base to ¼, apex obtuse, termen slightly rounded, somewhat oblique; fuscous, with irregularly scattered whitish scales, especially on margins, and with scattered strigulae of dark fuscous and blackish scales, but no defined markings: cilia fuscous, towards tips whitish. Hindwings fuscous, darker towards termen; cilia whitish-fuscous, with a fuscous subbasal line, towards tips whitish. Undersurface of hindwings grey (in *latomana* whitish).

Mount Enys, 5,600 ft., in January (Hudson); one specimen. Allied to *latomana*

Oecophoridae.

Cremnogenes monodonta n. sp.

♂♀. 17 mm. Head, palpi, antennae, thorax, and abdomen dark fuscous; antennal ciliations 4, whorled. Forewings elongate, costa gently arched, apex obtuse, termen very obliquely rounded; dark bronzy-purplish-fuscous; a small whitish-ochreous elongate mark on fold before middle of wing, and a few ochreous-whitish scales towards dorsum before tornus, in one specimen these markings confluent so as to form an obscure semioval dorsal patch: cilia bronzy-fuscous, mixed with darker towards base, beneath tornus with an ochreous-whitish spot. Hindwings dark bronzy-fuscous; cilia bronzy-fuscous, with darker subbasal shade.

Mount Holdsworth, 3,000–4,000 ft., in November (Stanley); three specimens.

Cryptolechia Zell.

As explained elsewhere, I have merged in this genus *Phaeosaces* Meyr. and *Leptosaces* Meyr.

Cryptolechia semnodes n. sp.

♂. 16 mm. Head, antennae, and thorax dark fuscous. Palpi dark fuscous, second joint sprinkled with pale ochreous. Abdomen dark purplish-fuscous, beneath with last four segments suffused with brassy-yellow. Forewings elongate, somewhat dilated posteriorly, costa gently arched, apex obtuse, termen slightly rounded, somewhat oblique; 7 to termen; dark fuscous, with slight bronzy-purplish tinge; second discal stigma very obscurely darker; two or three whitish-fuscous scales towards costa about middle and ¾: cilia dark fuscous. Hindwings blackish; cilia fuscous, basal third blackish.

Mount Arthur tableland, 4,200 ft., in February (Hudson); one specimen.

Cosmopterygidae.

Stathmopoda plumbiflua n. sp.

♂♀. 14–15 mm. Head, palpi, antennae, and thorax pale whitish-ochreous, shoulders and subdorsal stripes of thorax leaden-grey. Abdomen pale grey, anal tuft pale whitish-ochreous. Forewings very narrow, elongate-lanceolate; pale whitish-ochreous; extreme costal edge leaden-grey; a leaden-metallic subcostal streak from near base to beyond ¾; a similar streak running near above fold, confluent with subcostal towards base, continued very near above termen to apex; space between these two streaks more or less sprinkled with dark fuscous; a more or less marked leaden-metallic patch above dorsum towards base, edged posteriorly with some dark-fuscous scales; a slender leaden-metallic streak along posterior half of fold, terminated anteriorly with some dark-fuscous scales: cilia pale whitish-ochreous. Hindwings grey; cilia ochreous-grey-whitish.

West Plains, Invercargill, in November and January (Philpott): two specimens.

Glyphipterygidae.

Glyphipteryx leptosema Meyr.

One specimen, larger than type, 11 mm., with dorsal curved wedge-shaped whitish mark sharply defined (as also in a second example obtained

by myself from Auckland); bred from larvae in flower-stems of *Gahnia setifolia* (*Cyperaceae*) at Kaitoke, emerging in November (Hudson).

Glyphipteryx erastis n. sp.

♂♀. 8–10 mm. Head and thorax fuscous-bronze. Palpi with appressed scales, white, with four black bands. Antennae dark fuscous. Abdomen dark fuscous segmental margins somewhat whitish-suffused. Forewings elongate, costa gently arched, apex obtuse, termen somewhat sinuate, rather strongly oblique; rather dark bronzy-fuscous, median third suffused with bronzy-ochreous; an oblique whitish fascia near base, more or less indistinct towards costa, dilated into a triangular spot on lower half; a wedge-shaped rather oblique whitish mark from costa at ⅓, reaching more than half across wing; two narrow straight prismatic-silvery fasciae in and beyond middle, becoming whitish towards extremities, first more broadly; three short wedge-shaped whitish marks on costa posteriorly; an elongate black blotch along lower half of termen containing three violet-golden-metallic spots; space between this and costal marks traversed by six longitudinal suffused whitish streaks, separated by blackish scales; prismatic-silvery dots beneath costa near apex, at apex, and on termen beneath apex: cilia whitish, basal third bronzy-ochreous limited by a dark-fuscous line indented with whitish beneath apex. Hindwings and cilia dark fuscous.

Christchurch, Castle Hill (2,500 ft.), and Lake Wakatipu, from December to March; six specimens.

Glyphipteryx dichorda n. sp.

♂♀. 10–11 mm. Head and thorax rather dark bronzy-fuscous. Palpi loosely scaled, white, with four black bands, and anterior edge of terminal joint black towards apex. Antennae and abdomen dark fuscous. Forewings elongate, somewhat dilated posteriorly, costa gently arched, apex obtuse, termen faintly sinuate, oblique; dark shining fuscous-bronze; curved wedge-shaped white spots from dorsum at ¼ and beyond middle, reaching fold, second broader; light-fuscous rather oblique streaks, edged with dark-fuscous suffusion, from costa at ⅓ and before middle, reaching ⅓ across wing; a violet-golden-metallic dark-edged line from a whitish dot on costa at ⅔, rather abruptly bent round in disc, terminating in apex of second dorsal spot; a violet-golden-metallic dark-edged line from ⅘ of costa to tornus, curved or obtusely angulated in middle; three short whitish strigulae, dark-edged anteriorly, from costa towards apex; a violet-golden-metallic streak along lower part of termen, and a dot below apex: cilia whitish, basal third bronzy limited by a dark-fuscous line indented with white on subapical dot. Hindwings and cilia dark fuscous.

Whangarei and Wellington, in December; two specimens.

Simaethis antigrapha n. sp.

♂♀. 10–11 mm. Head and thorax dark fuscous irrorated with white. Palpi with whorls of dark-fuscous white-tipped scales. Antennae dark fuscous dotted with white. Abdomen dark fuscous, with series of white scales on segmental margins. Forewings suboblong, moderate, costa gently arched, apex obtuse, termen nearly straight, oblique; dark fuscous; basal patch and two irregular rather curved shades of purplish-white irroration almost wholly occupying anterior half of wing, last running from a small white spot before middle of costa to middle of dorsum; a small transverse-linear pale golden-metallic mark on end of cell; a line of purplish-white

irroration from [illegible] of costa to ⅔ of dorsum, median third irregularly curved outwards so as to touch following fascia; a straight fascia of purplish-white irroration from [illegible] of costa to tornus, this and preceding line both forming small white spots on costa; a series of scattered white scales before termen: cilia dark fuscous, with basal fourth blackish-fuscous, tips mixed with white, with a broad white patch extending from near apex to middle of termen except on basal fourth. Hindwings ovate-triangular, termen slightly rounded; dark fuscous; in ♀ an irregular white subterminal line on lower half of wing, in ♂ represented by a few scattered scales: cilia fuscous, more or less whitish-suffused towards middle of termen, with dark-fuscous subbasal shade, tips whitish.

Kaitoke and Karori, in December and March (Hudson); three specimens.

Simaethis iochondra n. sp.

♂. 16–17 mm. Head and thorax dark brown, with a few whitish specks. Palpi clothed with whorls of dark-fuscous whitish-tipped scales. Antennae dark fuscous dotted with white. Abdomen dark fuscous. Forewings sub-oblong, moderate, costa moderately arched, apex obtuse, termen rounded, oblique; dark bronzy-brown: basal area sprinkled with violet-whitish specks; a very undefined irregularly dentate shade of violet-whitish specks from ⅖ of costa to middle of dorsum; an irregular fascia of violet-whitish specks at ¾, constricted above middle, dilated on dorsum so as to coalesce with preceding shade; a light brownish-ochreous patch in disc between these; a terminal streak of ochreous-brown suffusion: cilia ochreous-brownish, mixed with darker at apex and tornus, tips whitish. Hindwings ovate-triangular, termen slightly rounded, hardly perceptibly sinuate; dark fuscous; cilia grey, with dark-fuscous subbasal shade, tips whitish.

Mount Holdsworth, Tararua Range, 3,000 ft., in February (Hudson); two specimens.

Tineidae.

Decadarchis hemiclistra n. sp.

♂ 15–17 mm., ♀ 22 mm. Head and thorax ochreous-whitish, sometimes brownish-tinged, hairs of forehead sometimes mixed with dark fuscous. Palpi whitish, second joint suffused externally with dark fuscous, beneath with whitish projecting scales increasing to apex, terminal joint moderate, slender, with appressed scales. Antennae fuscous-whitish. Abdomen whitish-fuscous. Forewings elongate, narrow, costa moderately arched, apex round-pointed, termen slightly sinuate, extremely oblique; ochreous-white, on dorsal half and towards apex in ♂ tinged with brownish in ♀ more strongly infuscated, with variable scattered dark-fuscous and black scales, especially in ♀; a dark-fuscous streak along costa from base to middle, posteriorly dilated and truncate; an elongate suffused dark-fuscous mark beneath costa about ⅔; a blackish-fuscous streak from ⅔ of disc to apex, interrupted before apex, edged above with an ochreous-whitish line: cilia ochreous-whitish, with more or less marked dark-fuscous post-median line, at apex with a blackish bar, round apex with a blackish-fuscous subbasal shade. Hindwings in ♂ whitish-grey, in ♀ light grey; cilia ochreous-whitish.

Wellington, in December (Hudson); reared from larvae and pupae in flower-stems of toetoe (*Arundo conspicua*), at Makara, emerging in November

and February (Sunley). The larval habit is very interesting. The natural food of species of this group of genera appears to be dead woody fibre.

Tinea dicharacta Meyr.

Tinea dicharacta Meyr., Proc. Linn. Soc. N.S.W., 1892, p. 536.

♀. 10 mm. (Australian ♂ 6 mm.). Head pale ochreous. Thorax dark fuscous. Forewings dark fuscous, with four fasciae represented principally by groups of two or three white strigulae each, indistinctly connected by glossy purplish-leaden striation, last supapical. Hindwings dark purplish-fuscous.

Wellington, in November (Hudson); one specimen. Described originally from one specimen, taken at Sydney, New South Wales, in November, which has hitherto remained unique. The species is a very distinct one, and its identity is undoubted. Mr. Hudson has another specimen, but regards the species as very rare; it is probably semi-domestic in habits.

Art. XI.—*A Revision of the Classification of New Zealand* Tortricina.

By E. Meyrick, B.A., F.R.S., F.Z.S.

Communicated by G. V. Hudson, F.E.S.

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I have lately been preparing a paper on the Australian species of *Tortricina*, and it seemed desirable to take the opportunity to revise the New Zealand species also. Considerable progress has been made in the study of the group since my paper in the "Transactions of the New Zealand Institute" for 1884; my views have been modified as to the relative value of some structural characters; the limits of the species, which are often very variable, are now better understood, and many additional forms have been discovered meanwhile. I have also corrected some unfortunate errors of identification. It should be understood that many of Walker's New Zealand types are in the most deplorable condition, sometimes reduced to one or two broken fragments. I therefore lately took up my whole collection of the group to the British Museum, in order to have the advantage of comparing all my material with the types, and I think I have now identified the whole of Walker's species of this group from Australia and New Zealand with approximate certainty.

In regard to structural characters, I have come to the conclusion that the costal fold of the male is not of value as a generic character, and have therefore abandoned its use. More stress, on the other hand, has been laid on certain differences in the neuration of the hindwings and on the structure of the palpi.

After careful study I have concluded that the curious genus *Isonomeutis* is not correctly referable to this group, and it is removed to the *Plutellidae*. I have been assisted in this determination by obtaining an apparently allied genus from Queensland which possesses distinct maxillary palpi. The genus may be distinguished from all New Zealand *Tortricina* by having 6 and 7 of hindwings parallel.

CARPOSINIDAE.

Ocelli absent. Forewings with tufts of scales on surface; 2 from posterior fifth of cell, 7 to termen, separate. Hindwings with or without basal pecten on lower margin of cell; 5 absent, 6 usually absent or rudimentary, parallel to 7 when present, 7 to apex.

Easily known by the peculiar neuration of hindwings. There are six Australian genera, but only one occurs in New Zealand.

1. Carposina H. S.

Carposina H. S., Schm. Eur., vol. 5, p. 38 (1855); type, *berberidella*. *Heterocrossa* Meyr., Proc. Linn. Soc. N.S.W., 1882, p. 178; type, *adreptella*.

Antennae in ♂ with moderate or long ciliations (1–4). Palpi long or very long, porrected, second joint with projecting scales above and beneath, terminal more or less concealed. Forewings: 8 separate. Hindwings with basal pecten on cell; in ♂ sometimes not developed; 3 and 4 stalked, 6 absent.

Principally characteristic of the Hawaiian Islands and Australia, with stragglers in North America and Europe.

1. *C. contactella* Walk., Cat., vol. 35, p. 1813; Meyr., Trans. Ent. Soc. Lond., 1905, p. 235.
   Wellington.

2. *C. thalamota* Meyr., Trans. N.Z. Inst.. 1908, p. 12.
   Invercargill.

3. *C. adreptella* Walk., Cat., vol. 29, p. 654; Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 698; *ib.*, Trans. N.Z. Inst. 1882, p. 66.
   Hamilton, Christchurch, Lake Wakatipu, Invercargill. Larva in shoots of *Rubus*.

4. *C. iophaea* Meyr., Trans. N.Z. Inst., 1906, p. 118.
   Invercargill.

5. *C. cryodana*, Meyr., Trans. N.Z. Inst., 1884, p. 148.
   Dunedin, Invercargill.

6. *C. exochana* Meyr., Trans. N.Z. Inst., 1887, p. 76.
   Masterton. Wellington, Nelson.

7. *C. charaxias* Meyr., Trans. N.Z. Inst., 1890, p. 98.
   Wellington.

8. *C. eriphylla* Meyr., Trans. N.Z. Inst., 1887, p. 76.
   Wellington.

9. *C. gonosemana* Meyr., Proc. Linn. Soc. N.S.W., 1882, p. 179; Trans. N.Z. Inst., 1882, p. 67: *epomiana* Meyr., Trans. N.Z. Inst., 1884, p. 149.
   Wellington, Nelson, Otira River, Dunedin.

Tortricidae.

Ocelli present. Forewings with 2 from before $\frac{3}{4}$ of lower margin of cell. Hindwings without basal pecten on lower margin of cell (except *Epalxiphora* and *Ctenopseustis*), 5 present.

This is the principal family in New Zealand and Australia, but not generally elsewhere. It is distinguished from the *Eucosmidae* by the absence of the basal pecten of cell in hindwings; but three genera which possess this pecten (*Ctenopseustis* and *Epalxiphora* in New Zealand, and *Sparganothis* in America and subsequently Europe) must notwithstanding be included in the family on a consideration of the sum of their characters, the occurrence of the structure being perhaps due to reversion. In no genus of *Eucosmidae* is the pecten absent.

2. Proselena Meyr.

Proselena Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 421; type, *annosana*. *Prothelymna* Meyr., Trans. N.Z. Inst., 1882, p. 57: type, *antiquana*.

Antennae in ♂ rather strongly ciliated. Palpi moderate, porrected, second joint dilated with rough scales above and beneath, terminal short. Thorax smooth. Forewings with 7 to termen, 8 separate. Hindwings with 3 from much before angle, remote and nearly equidistant from 2 and 4, 4 from angle, 5 rather approximated to 4 at base, transverse vein extremely oblique, 6 and 7 long-stalked.

I now restrict this genus in its original sense, removing from it those forms in which veins 3 and 4 of hindwings are approximated at base, which have no near relationship with the original type. The genus now includes only one Australian species and two from New Zealand.

10. *P. niphostrota* Meyr., Trans. N.Z. Inst., 1906, p. 117.
Wellington, Invercargill.

11. *P. antiquana* Walk., Cat., vol. 28, p. 307; *maoriana*, *ib.*, p. 308; *fusiferana*, *ib.*, p. 355; *spoliatana*, *ib.*, p. 356; *vetustana*, *ib.*, p. 358; *morosana*, *ib.*, p. 382; *accensana*, *ib.*, vol. 30, p. 983; *nephelotana* Meyr., Trans. N.Z. Inst., 1882, p. 57.
Christchurch.

3. Pyrgotis Meyr.

Pyrgotis Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 439; type, *insignana*.

Antennae in ♂ moderately strongly ciliated. Palpi moderate, subascending, second joint with rough projecting scales beneath and towards apex above, terminal moderate. Thorax with posterior crest. Forewings with 7 and 8 stalked, 7 to termen. Hindwings with 3–5 separate, equidistant, rather approximated towards base, 6 and 7 short-stalked.

Now restricted to one Australian and two New Zealand species.

12. *P. pyramidias* Meyr., Trans. Ent. Soc. Lond., 1901, p. 571.
Invercargill.

13. *P. eudorana* Meyr., Trans. N.Z. Inst., 1884, p. 143.
Taranaki.

4. Catamacta n.g.

Antennae in ♂ moderately ciliated. Palpi rather long, porrected, second joint with projecting scales above and beneath, terminal moderate. Thorax without crest. Forewings with 7 and 8 stalked, 7 to termen. Hindwings with 3 and 4 approximated at base. 5 more or less approximated to 4, 6 and 7 stalked.

Type, *gavisana* Walk. Contains only the following species, some of which I formerly wrongly referred to *Adoxophyes*, which is characterized by the peculiar position of vein 3 of forewings, which rises from lower margin of cell considerably before angle; this latter genus does not occur in New Zealand.

14. *C. trichroa* Meyr., Trans. Ent. Soc. Lond., 1901, p. 578.
 Whangarei.

15. *C. aureana* Feld., Reis. Nov., pl. 137, p. 47; *camelina* Meyr., Trans. N.Z. Inst., 1890, p. 97.
 Wellington.

16. *C. lotinana* Meyr., Trans. N.Z. Inst., 1882, p. 40.
 Christchurch. Larva on *Arundo conspicua*.

17. *C. gavisana* Walk., Cat., vol. 28, p. 312; ? *innotatana*, *ib.*, p. 333; *marginana*, *ib.*, p. 371: *porphyreana* Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 443; *aoristana*, *ib.*, p. 446; *conditana* Meyr. (*nec* Walk.), Trans. N.Z. Inst., 1882, p. 40.
 Auckland, Napier, Wellington, Nelson, Christchurch, Dunedin, Invercargill. Larva on *Genista* in gardens, but must also feed on a native plant.

5. Capua Steph.

Capua Steph., Ill. Brit. Ent., vol. 4, p. 171 (1834); type, *favillaceana*. *Epagoge* Hb., Verz., p. 389 (1826); ? type, *grotiana*. *Dichelia* Guen., Micr. Ind., p. 7 (1845); type, *grotiana*. *Teratodes* Guen., Micr. Ind., p. 34 (1845): type, *favillaceana*.

Antennae in ♂ ciliated. Palpi moderate, porrected, second joint with more or less projecting scales above and beneath, terminal short. Thorax usually with slight crest. Forewings with 7 and 8 stalked, 7 to termen. Hindwings with 3 and 4 connate or seldom stalked, 5 approximated to 4 at base, 6 and 7 stalked.

I do not adopt the name *Epagoge*, because (1) the application of it is dubious, as I do not admit the principle of accidental fixation by Stephens's use; and (2) I hold that the name *Capua*, which has over seventy years' use in a sense undoubtedly correct, is not to be overridden by an obsolete name now revived. Widely distributed, but much more numerous in Australia than elsewhere.

18. *C. cyclobathra* Meyr., Trans. N.Z. Inst., 1906, p. 114.
 Invercargill.

19. *C. zygiana* Meyr., Trans. N.Z. Inst., 1882, p. 39.
 Christchurch.

20. *C. tornota* Meyr., Trans. N.Z. Inst., 1906, p. 115.
 Invercargill.

21. *C. plagiatana* Walk., Cat., vol. 28, p. 370; Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 441; Trans. N.Z. Inst., 1882, p. 38: *recusana* Walk., Cat., vol. 28, p. 371: *luciplagana*, *ib.*, p. 381; Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 470; Trans. N.Z. Inst., 1882, p. 36: *punana* Feld., Reis. Nov., pl. 137, p. 43: *xylinana*, *ib.*, p. 44.
    Taranaki, Wellington, Blenheim, Christchurch, Otira River, Dunedin, Auckland Island. Larva on oak (*Quercus*), but must also feed on a native plant.
22. *C. plinthoglypta* Meyr., Trans. N.Z. Inst., 1891, p. 218.
    Wellington.
23. *C. semiferana* Walk., Cat., vol. 28, p. 306; Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 453; Trans. N.Z. Inst., 1882, p. 37: *detritana* Walk., Cat., vol. 28, p. 356: *admotella*, *ib.*, p. 485: *abnegatana*. *ib.*, vol. 30, p. 991: *constrictana*, *ib.*, vol. 35, p. 1785.
    Whangarei, Hamilton, Taranaki, Napier, Wellington, Nelson, Castle Hill, Christchurch, Dunedin, Invercargill. Walker's type of *constrictana* is said to be from Australia, but this is doubtless an error of record.

6. Eurythecta Meyr.

Eurythecta Meyr., Trans. N.Z. Inst., 1882, p. 56; type, *robusta*.

Antennae in ♂ ciliated. Palpi moderate, porrected, second joint with projecting scales above and beneath, terminal short. Thorax without crest. Forewings with 4 absent, 7 separate, to termen, or absent. Hindwings 6 and 7 approximated at base.

Confined to New Zealand, being a local development of the following genus. The first two species have vein 7 of the forewings absent, in the others it is present; the alliance being close in all other respects, and the genus being sufficiently defined as a whole, I think it needless to separate the two forms.

24. *E. robusta* Butl., Proc. Zool. Soc. Lond., 1877, p. 403, fig. 17; Meyr., Trans. N.Z. Inst., 1882, p. 56: *negligens* Butl., Proc. Zool. Soc. Lond., 1877, p. 404, fig. 18.
    Christchurch.
25. *E. zelaea* Meyr., Trans. Ent. Soc. Lond., 1905, p. 233.
    Dunedin.
26. *E. potamias* Meyr., Trans. N.Z. Inst., 1908, p. 11.
    Invercargill.
27. *E. paraloxa* Meyr., Trans. N.Z. Inst., 1906, p. 117.
    Invercargill.
28. *E. loxias* Meyr., Trans. N.Z. Inst., 1887, p. 74.
    Mount Arthur (4,000 ft.).
29. *E. eremana* Meyr., Trans. N.Z. Inst., 1884, p. 144.
    Castle Hill (2,500 ft.), Invercargill.

7. Epichorista n.g.

Antennae in ♂ ciliated. Palpi moderate, porrected, second joint with rough projecting scales above and beneath, terminal short. Thorax without crest. Forewings with 7 separate, to termen. Hindwings with 3 and 4

separate, approximated at base, 5 rather approximated to 4 at base, 6 and 7 closely approximated towards base or seldom stalked.

Type, *E. hemionana*. Veins 6 and 7 of hindwings are normally stalked in *siriana* only, but it does not appear necessary to separate the species. The genus is a development of *Tortrix*, besides the seven New Zealand species there are seven Australian, and I have recently obtained three from South Africa.

30. *E. siriana* Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 521, Trans. N.Z. Inst., 1882, p. 43.
Hamilton.

31. *E. hemionana* Meyr., Trans. N.Z. Inst., 1882, p. 43.
Lake Guyon, Arthur's Pass, Dunedin.

32. *E. elephantina* Meyr., Trans. N.Z. Inst., 1884, p. 143.
Arthur's Pass (4,700 ft.).

33. *E. aspistana* Meyr., Trans. N.Z. Inst., 1882, p. 42.
Porter's Pass.

34. *E. emphanes* Meyr., Trans. Ent. Soc. Lond., 1901, p. 571.
Mount Peel.

35. *E. zatrophana* Meyr., Trans. N.Z. Inst., 1882, p. 46; *ib.*, 1884, p. 144.
Mount Arthur (2,600 ft.), Arthur's Pass (2,600–3,000 ft.), Christchurch.

36. *E. eribola* Meyr., Trans. N.Z. Inst., 1888, p. 156.
Otira River.

8. Ascerodes Meyr.

Ascerodes Meyr., Trans. Ent. Soc. Lond., 1905, p. 234; type, *prochlora*.

Antennae in ♂ biciliated with long fascicles. Palpi moderate, porrected, triangularly scaled with long rough projecting hairs diminishing to apex. Thorax without crest, hairy beneath. Forewings with 7 separate, to termen. Hindwings with 3 and 4 separate, approximated at base, 5 parallel, 6 and 7 closely approximated towards base.

At present contains only the one species.

37. *A. prochlora* Meyr., Trans. Ent. Soc. Lond., 1905, p. 231.
Humboldt Range (4,000 ft.).

9. Tortrix L.

Tortrix L., Syst. Nat. (ed. 10), vol. 1, p. 496 (1758); type, *viridana*.

Antennae in ♂ ciliated. Palpi moderate or long, porrected, second joint with rough projecting scales above and beneath, terminal short or moderate. Thorax without crest. Forewings with 7 separate, to termen. Hindwings with 3 and 4 connate, 5 approximated towards base, 6 and 7 closely approximated towards base.

This extensive genus is largely represented in all regions. The generic synonymy is considerable, but is not given here, as not affecting the New Zealand species.

38. *T. pictoriana* Feld., Reis. Nov., pl. 137, p. 55; Meyr., Trans. N.Z. Inst., 1882, p. 51.
Christchurch, Mount Hutt, Lake Guyon, Lake Wakatipu.

39. *T. philopoana* Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 515; Trans. N.Z. Inst., 1882, p. 52.
Hamilton.

40. *T. leucaniana* Walk., Cat., vol. 28, p. 370; Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 517; Trans. N.Z. Inst., 1882, p. 53: *intactella* Walk., Cat., vol. 29, p. 652: *pauculana*, *ib.*, vol. 35, p. 1781.
Whangarei, Auckland, Hamilton. Taranaki, Napier, Wellington, Nelson, Christchurch, Invercargill.

41. *T. demiana* Meyr., Trans. N.Z. Inst., 1882, p. 51.
Rakaia.

42. *T. indigestana* Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 520.
Whangarei; common in Australia, whence it may have been artificially introduced. Larva in Australia on *Hibbertia linearis*, but very likely also on other plants.

43. *T. aerodana* Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 520; Trans. N.Z. Inst., 1882, p. 53.
Whangarei, Hamilton, Napier.

44. *T. charactana* Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 492; Trans. N.Z. Inst., 1882, p. 50.
Auckland, Nelson. Christchurch.

45. *T. orthropis* Meyr., Trans. Ent. Soc. Lond., 1901, p. 573.
Wellington, Nelson, Dunedin.

46. *T. postvittana* Walk., Cat., vol. 28, p. 297; Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 502: *retractana* Walk., Cat., vol. 28, p. 288: *scitulana*, *ib.*, p. 298: *basialbana*, *ib.*, p. 299: *secretana*, *ib.*, p. 300: *consociana*, *ib.*, p. 311: *reversana*, *ib.*, p. 321: *foedana*, *ib.*, p. 321: *vicariana* Walk., Char. Het., p. 82.
Wellington, Christchurch, undoubtedly introduced from Australia, where is is plentiful. Larva polyphagous, on *Grevillea*, *Boronia*, &c.; has been bred from apples.

47. *T. torogramma* Meyr., Trans. Ent. Soc. Lond,, 1897, p. 388.
Wellington.

48. *T. conditana* Walk., Cat., vol. 28. p. 306; *enoplana* Meyr., Trans. N.Z. Inst., 1882, p. 49; *astrologana* Meyr.. Trans. N.Z. Inst., 1888, p. 156.
Wellington. This is a very variable species, hitherto not understood; on the other hand, I think the Tasmanian specimen which I associated with *astrologana* is really not identical.

49. *T. syntona* Meyr., Subantarctic Islands of N.Z., vol. 1, p. 73.
Auckland Island.

50. *T. alopecana* Meyr., Trans. N.Z. Inst., 1884, p. 147.
Bealey River. Larva in spun shoots of *Phyllocladus alpinus*.

51. *T. excessana* Walk., Cat.. vol. 28, p. 303; Meyr., Proc. Linn. Soc. N.S.W., 1881. p. 491; Trans. N.Z. Inst., 1882, p. 48: *biguttana* Walk., Cat., vol. 28, p. 305: ? *abjectana*, *ib.*, vol. 35, p. 1781.
Auckland, Wellington, Nelson, Christchurch, Dunedin. Larva between joined leaves of *Panax arboreum*, and probably other shrubs.

52. *T. acrocausta* Meyr., Trans. N.Z. Inst., 1906, p. 116.
Christchurch, Invercargill.

53. *T. fervida* Meyr., Trans. Ent. Soc. Lond., 1901, p. 572.
Kaitoke.

54. *T. molybditis* Meyr., Trans. N.Z. Inst., 1906, p. 116.
Wellington. Larva case-bearing, on moss.

55. *T. crypsidora* Meyr., Trans. N.Z. Inst., 1908, p. 11.
Tararua Range (3,500 ft.), Invercargill.

10. Epalxiphora Meyr.

Epalxiphora Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 647: type, *axenana*.

Antennae in ♂ ciliated. Palpi moderate, subascending, second joint with dense tolerably appressed scales somewhat expanded towards apex, terminal moderate. Thorax with large erect crest on each side of back, and small double posterior crest. Forewings with 7 and 8 stalked, 7 to termen. Hindwings with basal pecten on lower margin of cell, 3 and 4 separate, 3, 4, and 5 more or less closely approximated towards base, 6 and 7 stalked.

The single peculiar species which constitutes this genus is very variable, but can be recognized from all others by the triple thoracic crest.

56. *E. axenana* Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 648; Trans. N.Z. Inst., 1882, p. 58; *ib.*, 1884, p. 147.
Auckland, Taranaki, Palmerston, Wellington.

11. Ctenopseustis Meyr.

Ctenopseustis Meyr., Trans. N.Z. Inst., 1884, p. 146; type, *obliquana*.

Antennae in ♂ shortly ciliated. Palpi moderate, porrected, second joint with projecting scales above and beneath, terminal short. Thorax without crest. Forewings with 7 separate, to termen. Hindwings with basal pecten on lower margin of cell, 3 and 4 connate, 5 approximated to 4 at base, 6 and 7 closely approximated towards base.

Also including only one very variable species.

57. *C. obliquana* Walk., Cat., vol. 28, p. 302; Meyr., Trans. N.Z. Inst., 1882, p. 60; *ib.*, 1884, p. 146: *spurcatana* Walk., Cat., vol. 28, p. 305; Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 487: *servana* Walk., Cat., vol. 28, p. 306: *priscana*, *ib.*, p. 307: *congestana*, *ib.*, p. 308: *transtrigana*, *ib.*, p. 354: *turbulentana*, *ib.*, p. 355: *cuneiferana*, *ib.*, vol. 35, p. 1780: *contractana*, *ib.*, p. 1782: *ropeana* Feld., Reis. Nov., pl. 137, p. 45: *taipana*, *ib.*, p. 46: *herana*, *ib.*, p. 52: *inana* Butl., Proc. Zool. Soc. Lond., 1877, p. 403, fig. 13.
Whangarei, Auckland, Hamilton, Taranaki, Napier, Wellington, Nelson, Christchurch, Dunedin. Larva amongst spun leaves of *Veronica*, *Lonicera*, &c.

12. Harmologa Meyr.

Harmologa Meyr., Trans. N.Z. Inst., 1882, p. 44; type, *oblongana*.
Trachybathra Meyr., Trans. N.Z. Inst., 1906, 114; type, *scoliastis*.

Antennae in ♂ ciliated. Palpi moderate or long, porrected, second joint with rough projecting scales above and beneath, terminal moderate. Thorax with crest. Forewings with 7 separate, to termen. Hindwings with 3, 4, 5 approximated towards base, 6 and 7 stalked.

Besides the following species there are two Australian. The example described as the type of *Trachybathra* appears to be a singular instance of abnormal neuration; it has 7 and 8 of forewings stalked and 4 of hindwings absent, but a second example subsequently obtained has the normal structure of *Harmologa*. These two examples unquestionably represent the same species, and the only possible conclusion seems that the first is a structural aberration or monstrosity.

58. *H. amplexana* Zell., Zool. Bot. Ver., 1875, p. 222; Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 494; Trans. N.Z. Inst., 1882, p. 47: *vilis* Butl., Proc. Zool. Soc. Lond., 1877, p. 402, fig. 15.
Wellington, Greymouth, Christchurch, Dunedin, Lake Wakatipu.

59. *H. aenea* Butl., Proc. Zool. Soc. Lond., 1877, p. 402; Meyr., Trans. N.Z. Inst., 1882, p. 46.
Porter's Pass, Mount Hutt.

60. *H. siraea* Meyr., Trans. N.Z. Inst., 1884, p. 145.
Arthur's Pass (4,500 ft.), Mount Arthur (4,000–4,500 ft.).

61. *H. epicura* n. sp.

♂. 16 mm. Head, palpi, and thorax fuscous mixed with ferruginous-brownish. Antennal ciliations ¾. Abdomen bronzy-grey. Forewings elongate, posteriorly dilated, costa gently arched, somewhat bent in middle, with fold reaching to middle, apex obtuse, termen almost straight, rather oblique: fuscous, somewhat tinged with ferruginous-brownish; markings indefinite, formed by brownish suffusion mixed with ferruginous and pale-ochreous scales; a moderate basal patch, outer edge somewhat curved; central fascia moderately broad, oblique, rather narrowed towards costa; apical area beyond a line from ⅔ of costa to tornus irregularly striated: cilia pale greyish-ochreous somewhat mixed with ferruginous-ochreous, with a purplish-grey subbasal shade. Hindwings dark grey; cilia whitish-grey, with grey subbasal shade.

Castle Hill (3,000 ft.), in January; one specimen.

62. *H. achrosta* Meyr., Trans. Ent. Soc. Lond., 1901, p. 572.
Mount Arthur.

63. *H. scoliastis* Meyr., Trans. N.Z. Inst., 1906, p. 114.
Lake Wakatipu.

64. *H. oblongana* Walk., Cat., vol. 28, p. 303; Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 489; Trans. N.Z. Inst., 1882, p. 45: *inaptana* Walk., Cat., vol. 28, p. 304: *cuneigera* Butl., Cist. Ent., vol. 2, p. 559.
Blenheim, Christchurch, Castle Hill, Dunedin, Lake Wakatipu.
Larva in dense web on *Discaria toumatou*, and probably other plants.

65. *H. sisyrana* Meyr., Trans. N.Z. Inst., 1882, p. 44.
Wellington, Christchurch.

66. *H. hemiclista* Meyr., Trans. Ent. Soc. Lond., 1905, p. 233.
Wellington.

13. Cnephasia Curt.

Cnephasia Curt., Brit. Ent., vol. 3, p. 100 (1826); type, *pascuana*. *Sciaphila* Treits., Schmett. Eur., vol. 7, p. 233 (1829); type, *wahlbomiana*. *Dipterina* Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 523; type, *imbriferana*.

Antennae in ♂ ciliated. Palpi moderate or long, porrected, second joint with projecting scales above and beneath, terminal moderate. Thorax

sometimes with small crest. Forewings with 7 separate, to termen. Hindwings with 3 and 4 connate, 5 approximated to 4, 6 and 7 stalked.

A rather extensive genus, but principally in temperate regions.

67. *C. incessana* Walk., Cat., vol. 28, p. 304; Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 529; Trans. N.Z. Inst., 1882, p. 55.
Auckland, Taranaki, Christchurch.

68. *C. jactatana* Walk., Cat., vol. 28, p. 317; Meyr., Trans. N.Z. Inst., 1882, p. 54: *flexivittana* Walk., Cat., vol. 28, p. 353: *privatana*, *ib.*, p. 382: *voluta* Feld., Reis. Nov., pl. 137, p. 39.
Whangarei, Auckland, Taranaki, Palmerston, Makotuku, Wellington, Nelson, Christchurch. Dunedin.

69. *C. sphenias* Meyr., Trans. N.Z. Inst., 1908, p. 11.
Invercargill.

70. *C. latomana* Meyr., Trans. N.Z. Inst., 1884, p. 145.
Mount Arthur (4,400–4,600 ft.), Arthur's Pass (4,700 ft.).

71. *C. petrias* Meyr., Trans. Ent. Soc. Lond., 1901, p. 572.
Invercargill.

72. *C. imbriferana* Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 527; Trans. N.Z. Inst., 1882, p. 55.
Auckland, Wellington, Christchurch, Dunedin.

EUCOSMIDAE.

Ocelli present. Forewings with 2 from before $\frac{3}{4}$ of lower margin of cell. Hindwings with basal pecten on lower margin of cell, 5 present.

This family is very scantily represented in New Zealand, though very numerous throughout the Northern Hemisphere. The total absence of the very large genus *Argyroploce* is particularly noticeable.

14. Hendecasticha Meyr.

Hendecasticha Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 691; type. *aethaliana*.

Antennae in ♂ ciliated, with an excavated notch in stalk towards base. Palpi moderate, porrected, second joint with dense rough projecting hairs above and beneath, terminal short. Thorax without crest. Forewings with 7 absent, 8 to costa. Hindwings with 4 absent, 5 somewhat approximated towards 3 at base, 6 and 7 stalked.

Contains only the single species; a local modification of *Spilonota*.

73. *H. aethaliana* Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 692; Trans. N.Z. Inst., 1882, p. 64.
Hamilton.

15. Spilonota Steph.

Spilonota Steph., Cat. Brit. Ins., p. 173 (1829); type, *ocellana*. *Tmetocera* Led., Wien. Ent. Mon., 1859, p. 367; type, *ocellana*. *Monilia* Walk., Cat., vol. 35, p. 1741 (1866); type, *semicanella*. *Strepsiceros* Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 678 (*praeocc.*); type, *ejectana*. *Strepsicrates* Meyr., Trans. N.Z. Inst., 1886, p. 73; type, *ejectana*.

Antennae in ♂ ciliated, with an excavated notch in stalk towards base. Palpi moderate, porrected, second joint with dense rough projecting scales

above and beneath, sometimes tufted beneath, terminal short. Thorax without crest. Forewings 7 separate, to termen. Hindwings with 3 and 4 long-stalked or coincident, 5 closely approximated to 4 at base, 6 and 7 approximated towards base.

A genus of moderate extent and wide distribution, but principally Australian; two of the New Zealand species occur also in Australia.

74. *S. charopa* Meyr., Trans. N.Z. Inst., 1887, p. 73.
Whangarei, Auckland.

75. *S. dolopaea* Meyr., Trans. Ent. Soc. Lond., 1905, p. 232.
Wellington.

76. *S. parthenia* Meyr., Trans. N.Z. Inst., 1887, p. 73.
Auckland.

77. *S. zopherana* Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 688; Trans. N.Z. Inst., 1882, p. 64.
Hamilton, Wellington, Christchurch Dunedin. Also in Australia.

78. *S. emplasta* Meyr., Trans. Ent. Soc. Lond., 1901, p. 571.
Invercargill.

79. *S. chaophila* Meyr., Trans. N.Z. Inst., 1908, p. 10.
Wellington.

80. *S. ejectana* Walk., Cat., vol. 28, p. 350; Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 681; Trans. N.Z. Inst., 1882, p. 63: *servilisana* Walk., Cat., vol. 28, p. 356: *saxana*, *ib.*, p. 357: *ligniferana*, *ib.*, p. 363.
Hamilton, Palmerston, Wellington, Christchurch, Lake Wakatipu. Also common and widely distributed in Australia. Larva amongst spun leaves and shoots of *Kunzea capitata* and *Darwinia fasciculata*.

16. Eucosma Hb.

Eucosma Hb., Zutr. Exot. Schm., p. 28 (1823); type, *circulana*. *Epiblema* Hb., Verz., p. 365 (1826); type, *foenella*. *Protithona* Meyr., Trans. N.Z. Inst., 1882, p. 62; type, *fugitivana*. *Exoria* Meyr., Trans. N.Z. Inst., 1882, p. 65; type, *mochlophorana*. *Parienia* Berg., Com. Mus. Buen. Air., vol. 1, p. 78 (1899); type, *mochlophorana*.

Antennae in ♂ ciliated. Palpi moderate, porrected, second joint with dense rough projecting scales above and beneath, terminal short. Thorax without crest. Forewings with 7 separate, to termen. Hindwings with 3 and 4 usually stalked, sometimes connate or coincident, 5 approximated to 4 at base, 6 and 7 approximated towards base.

A very extensive genus, but principally characteristic of the Northern Hemisphere. The full generic synonymy includes a large number of additional names.

81. *E. mochlophorana* Meyr., Trans. N.Z. Inst., 1882, p. 65.
Rakaia, Lumsden.

82. *E. aphrias* Meyr., Trans. Ent. Soc. Lond., 1901, p. 578.
Invercargill.

83. *E. fugitivana* Meyr., Trans. N.Z. Inst., 1882, p. 62.
Lake Coleridge.

17. Bactra Steph.

Bactra Steph., Ill., p. 124 (1834); type, *lanceolana*. *Aphelia* Steph., Cat. Brit. Ins., p. 180 (1829) (*praeocc.*); type. *lanceolana*. *Chiloides* Butl., Ann. Mag. N.H. (5), vol. 7, p. 392 (1881); type, *straminea*. *Noteraula* Meyr., Trans. N.Z. Inst., 1891, p. 217; type, *noteraula*.

Antennae in ♂ ciliated. Palpi moderate or long, porrected, second joint with projecting scales above and beneath, terminal short. Thorax without crest. Forewings with 7 separate, to termen. Hindwings with 3, 4, 5 closely approximated at base, 6 and 7 stalked.

A rather considerable genus of wide distribution, of which the species are very similar and puzzling, and have been involved in much confusion. Some of the species, and very possibly all, are attached to various species of *Juncus*. There is often much variability, but the length of palpi, form of forewings, and colour of hindwings are important and reliable characters.

84. *B. noteraula* Wals., Faun. Haw., vol. 1, p. 689; *straminea* Meyr. (*nec* Butl.), Trans. N.Z. Inst. 1884, p. 142.
Taranaki, Wanganui, Otaki, Mangatarera River, Nelson.

85. *B. optanias* n. sp.
♀. 17–18 mm. Head and thorax light brownish-ochreous, sometimes suffused with light brown-reddish, thorax sometimes mixed with grey. Palpi $2\frac{1}{2}$, whitish-ochreous sometimes partially suffused with light brown-reddish two oblique bands and scales of second joint beneath suffused with grey base whitish. Abdomen pale grey or whitish-grey. Forewings elongate, narrow, posteriorly slightly dilated, costa slightly arched, apex obtuse. termen straight, oblique; pale brownish-ochreous, sometimes much suffused with ferruginous, variably sprinkled or sometimes largely irrorated with fuscous, veins posteriorly sometimes marked with fuscous lines; costa with short oblique strigulae of dark-fuscous irroration, between which on posterior half are longer oblique leaden-metallic marks, some of which are sometimes continued as indistinct irregular striae across wing; sometimes a broad suffused median streak of blackish irroration from base to apex, or in its place a longitudinal series of several irregular black spots or marks: cilia pale ochreous or grey, more or less sprinkled with black. Hindwings grey-whitish, apex somewhat suffused with grey; cilia grey-whitish, round apex greyer, with grey subbasal line.
Hamilton, in January; three specimens. Also widely distributed in Australia, but the above description is taken solely from my New Zealand examples.

86. *B. sideritis* Meyr., Trans. Ent. Soc. Lond., 1905, p. 232.
Wellington (?).

18. Laspeyresia Hb.

Laspeyresia Hb., Verz., p. 381 (1826); type, *corollana*. *Carpocapsa* Tr., Schmett. Eur., vol. 7, p. 231; type, *pomonella*.

Antennae in ♂ ciliated. Palpi moderate, more or less ascending, second joint arched, with short projecting scales beneath, terminal joint short. Thorax without crest. Forewings with 7 separate, to termen. Hindwings with 3 and 4 connate or stalked 5 nearly parallel to 4, 6 and 7 approximated towards base.

A considerable genus, generally distributed; but only represented in New Zealand by a single introduced species.

87. *L. pomonella* Linn., Syst. Nat., vol. 10, p. 538; Meyr., Proc. Linn. Soc. N.S.W., 1881, p. 657; Trans. N.Z. Inst., 1882, p. 61.
Wellington, Nelson, Christchurch. Larva in apples; a well-known pest, now nearly cosmopolitan.

Index of Specific Names.

The references are to the specific numbers in the preceding list. Names in italics are synonyms.

Addendum.

The following names are not included in the above list, in the absence of certain identification :—

Sciaphila infimana Walk., Cat., vol. 30, p. 986.

Greatly damaged, but appears to be a species otherwise unknown to me, allied to *Spilonota*.

Teras punctilineana Walk., Cat., vol. 35, p. 1780.

Type lost. I cannot recognize the description.

Paedisca mahiana Feld., Reis. Nov., pl. 137, p. 40.

Apparently a distinct insect, but it is highly probable that the alleged New Zealand origin is a mistake.

Teras flavescens Butl., Proc. Zool. Soc. Lond., 1877, p. 402.

This is apparently a *Tortrix* allied to *excessana* and *acrocausta*; perhaps a good species otherwise unknown, but might be an abnormal variety.

Art. XII.—*Additions to the Coleopterous Fauna of the Chatham Islands.*

By Major T. Broun, F.E.S.

[*Read before the Auckland Institute, 22nd November, 1910.*]

In my last paper (Trans. N.Z. Inst., 1909, vol. 42, p. 306) it was shown that, excluding introduced beetles, forty-five species of *Coleoptera* had been found within the group. The number, as will be seen on referring to the following list, has now been increased to 106.

This considerable augmentation, by far the largest ever made, is the result of about twenty months' collecting on Pitt Island, between June, 1906, and January, 1908.

The insects were sent to me for examination in June last by Mr. E. R. Waite, Curator of the Canterbury Museum, who whilst on a visit to Pitt Island induced Mr. T. Hall, now residing at Methven, to devote all his spare time to searching for insects. This work was carried on throughout winter as well as summer, and often during the night, and Mr. Hall generously acknowledges the willing assistance rendered by his friend Mr. R. E. Paynter.

The beetles thus secured belong to thirty different groups. Some live on the sea-shore, others in solid timber, under loose bark and old logs, and many frequent flowering-shrubs.

As many of the older species were included in this collection, it may be regarded as fairly representative of the coleopterous fauna of Pitt Island —probably of the whole group.

Twenty-seven species proved to be new, two being the exponents of new genera; the remaining thirty-four are common to New Zealand as well as the Chatham Islands, but none indicate any close relationship to subantarctic genera.

The species are numbered consecutively in continuation of the system inaugurated in my first paper, published in volume 41 of the "Transactions of the New Zealand Institute." This method will be found very useful in labelling specimens when named, and will save time when several species are alluded to in correspondence.

As the formation of other collections in course of time may be confidently anticipated, it has been deemed expedient to add a few suggestions which, if attended to, will make the work of mounting specimens for microscopical inspection very much easier, and far more satisfactory to all concerned.

Insects should never be immersed in alcohol: it makes them very tough, and, if dried afterwards, very brittle. Before insects can be properly named and described, more especially the smaller kinds, they must be mounted on cardboard with the legs and antennae fully displayed in something like their natural positions. Any attempt to effect this in the case of alcoholic specimens is almost sure to result in mutilation, the slightest pressure of a setting-needle being sufficient to break a slender limb or joint. Generally the most important parts snap off, or will not bend at all, and in the case of many weevils the rostrum cannot be got out of the pectoral canal without detaching the whole thorax from the hind body. Naturalists are not likely to look at such damaged specimens a second time.

Beetles should be killed in a wide-mouthed bottle containing cyanide of potassium or freshly bruised laurel-leaves. When dead they should be transmitted from time to time by the first opportunity, amongst chopped-up laurel-leaves, or, if these cannot be obtained, some other green leaves off shrubs. They should never be packed amongst cotton or wool, as their claws become entangled with the fine fibres.

Group CNEMACANTHIDAE.

46. *Mecodema alternans* Castelnau, Man. N.Z. Coleopt., p. 10.

Group ANCHOMENIDAE.

47. *Anchomenus lawsoni* Bates, Man. N.Z. Coleopt., p. 23.
48. *Cyclothorax insularis* Motschulsky, Man. N.Z. Coleopt., p. 29.

Group FERONIDAE.

49. *Trichosternus antarcticus* Chaudoir, Man. N.Z. Coleopt., p. 31.

Group ANISODACTYLIDAE.

50. *Euthenarus puncticollis* Bates, Man. N.Z. Coleopt., p. 53.
51. *Allocinopus latitarsis* Broun, sp. nov.

Group STAPHYLINIDAE.

52. *Quedius antipodus* Sharp, Man. N.Z. Coleopt., p. 1028.

Group OMALIDAE.

53. *Omalium fossigerum* Eppelsheim.
54. ,, *robustum* Broun, sp. nov.

Group SILPHIDAE.

55. *Choleva brunneipes* Broun, sp. nov.

Group NITIDULIDAE.

56. *Epuraea antarctica* White, Man. N.Z. Coleopt., p. 169.

Group COLYDIIDAE.

57. *Enarsus bakewellii* Pascoe, Man. N.Z. Coleopt., p. 199.
58. *Tarphiomimus acuminatus* Broun, Man. N.Z. Coleopt., p. 183.
59. *Ulonotus asper* Sharp, Man. N.Z. Coleopt., p. 189.
60. ,, *plagiatus* Broun, sp. nov.
61. *Coxelus mucronatus* Broun, sp. nov.
62. *Pycnomerus mediocris* Broun, sp. nov.

Group BOTHRIDERIDAE.

63. *Bothrideres paynteri* Broun, sp. nov.

Group CUCUJIDAE.

64. *Chaetosoma scaritides* Westwood, Man. N.Z. Coleopt., p. 767.

Group DERMESTIDAE.

65. *Trogoderma signatum* Sharp, Man. N.Z. Coleopt., p. 240.
66. ,, *pictulum* Broun, sp. nov.

Group Aphodiidae.

67. *Aphodius sulcatissimus* Broun, sp. nov.

Group Elateridae.

68. *Amychus candezei* Pascoe, Trans. N.Z. Inst., vol. 9, p. 416.

Group Dascyllidae.

69. *Cyphon acerbus* Broun, Man. N.Z. Coleopt., p. 778.

Group Melyridae.

70. *Dasytes pittensis* Broun, sp. nov.

Cissidae.

71. *Cis undulatus* Broun, Man. N.Z. Coleopt., p. 347.

Group Trachyscelidae.

72. *Phycosecis atomaria* Pascoe, Man. N.Z. Coleopt., p. 359.

Group Melandryidae.

73. *Ctenoplectron vittatum* Broun, Man. N.Z. Coleopt., p. 844.

Group Lagriidae.

74. *Lagrioda brounii* Pascoe, Man. N.Z. Coleopt., p. 408.

Group Otiorhynchidae.

75. *Thotmus halli* Broun, gen. & sp. nov.
76. *Platyomida versicolor* Broun, sp. nov.

Group Rhyparosomidae.

77. *Phrynixus asper* Broun, sp. nov.

Group Cylindrorhinidae.

78. *Hadramphus spinipennis* Broun, gen. & sp. nov.

Group Erirhinidae.

79. *Praolepra squamosa* Pascoe, Man. N.Z. Coleopt., p. 454.
80. *Stephanorhynchus curvipes* White, Man. N.Z. Coleopt., p. 462.

Group Cryptorhynchidae.

81. *Aphocoelus versicolor* Broun, Ann. Mag. Nat. Hist., ser. 8, vol. 4, p. 138.
82. *Psepholax barbifrons* White, Man. N.Z. Coleopt., p. 480.
83. *Kentraulax flavisetosus* Broun, sp. nov.
84. *Mesoreda setigera* Broun, Man. N.Z. Coleopt., p. 488.
85. *Ectopsis ferrugalis* Broun, Man. N.Z. Coleopt., p. 719.
86. *Tychanus costatus* Broun, sp. nov.*
87. *Acalles lineirostris* Broun, sp. nov.
88. " *subcarinatus* Broun, sp. nov.
89. *Xenacalles squamiventris* Broun, gen. & sp. nov.
90. *Paranomocerus spiculus* Redtenbacher, Man. N.Z. Coleopt., p. 505.
91. *Rhyncodes ursus* White, Man. N.Z. Coleopt., p. 502.

* This species will be described in a subsequent paper.

Group Cossonidae.

92. *Pentarthrum zealandicum* Wollaston, Man. N.Z. Coleopt., p. 508.
93. „ *dissimilum* Broun, sp. nov.
94. „ *auripilum* Broun, sp. nov.
95. *Torostoma apicale* Broun, Man. N.Z. Coleopt., p. 509.
96. *Agastegnus ornatus* Broun, sp. nov.
97. *Phloeophagosoma corvinum* Wollaston, Man. N.Z. Coleopt., p. 530.
98. „ *dilutum* Wollaston, Man. N.Z. Coleopt., p. 531.
99. *Arecophaga varia* Broun, Man. N.Z. Coleopt., p. 534.

Group Anthribidae.

100. *Anthribus cristatellus* Broun, sp. nov.
101. „ *propinquus* Broun, sp. nov.
102. „ *pilicornis* Broun, sp. nov.

Group Lamiidae.

103. *Somatidia waitei* Broun, sp. nov.
104. „ *vicina* Broun, sp. nov.

Group Galerucidae.

105. *Phyllotreta nitida* Broun, Man. N.Z. Coleopt., p. 636.

Group Coccinellidae.

106. *Scymnus macrostictus* Broun, sp. nov.

Introduced.

Ptinus fur. European.

Group Anisodactylidae.

Allocinopus Broun. Ann. Mag. Nat. Hist., ser. 7, vol. 2, p. 607.

51. **Allocinopus latitarsis** sp. nov.

Subdepressed, nitid, dark fuscous, sides of thorax narrowly, of the elytra more broadly, fusco-rufous; femora and upper half of tibiae light yellowish-brown, the latter piceous towards the extremity; antennae and tarsi somewhat variegate, generally fusco-rufous.

Head smooth, with elongate frontal impressions, a single setigerous puncture at each front angle of the epistome and also near the middle of each eye; including the large and prominent eyes, it is about as broad as the thorax; labrum large, sex-setose. Thorax quite a third broader than long, widest before the middle, gradually narrowed towards the obtuse posterior angles; its sides moderately rounded, with well-developed and somewhat reflexed margins, base subtruncate, apex slightly incurved; the dorsal groove does not attain the apex, basal fossae large, situated nearer to the sides than the middle, there is no other definite sculpture, the seta at each side is placed before the middle. Elytra oblong, broader than thorax, nearly thrice its length, with oblique not at all prominent apices; their striae are well marked and simple, and there is a short scutellar groove on each, interstices impunctate and nearly plane, the marginal punctures are distinct near the base and apex but absent near the middle.

Tibiae finely setose inwardly, with spiniform setae externally, the intermediate pair particularly; the front pair incrassate.

Male.—Tarsi with dense grey squamiform vestiture and elongate lateral setae underneath; basal joint of the anterior subtriangular, joints 2–4 strongly and equally dilated, about twice as broad as they are long, 2nd and 3rd cordate, 4th entire below, deeply excavate in front, 5th nearly as long as the preceding two combined; the intermediate pair of similar structure, not quite as much expanded, their 5th joint equals the preceding three in length; the posterior with elongate-triangular articulations, 1st and 2nd equal, 4th shorter than 3rd.

Female.—Anterior tarsi not dilated, joints 2–4 somewhat cordiform, joints 1–3 of the middle pair triangular, 4th cordiform.

Antennae sometimes testaceous and more or less maculate with brown, they extend backwards to the base of the elytra, their 1st and 2nd joints and the base of the 3rd are glabrous.

The dilated joints of the intermediate tarsi of the male, and their vestiture, in conjunction with the rounded posterior angles of the thorax, will enable this species to be separated from its New Zealand congeners.

Length, 8–9 mm.; breadth, nearly 4 mm.

Pitt Island.

Found by Mr. T. Hall.

Group Omalidae.

Omalium Gravenhorst. Man. N.Z. Coleopt., p. 115.

54. **Omalium robustum** sp. nov.

Robust, elongate, subdepressed; hind-body with distinct slender greyish setae, thorax and elytra glabrous; nigrescent, subopaque, the front of the head and parts of thorax shining, legs and antennae variable, generally pale castaneous, the terminal half of these latter darker.

Head evidently smaller than thorax, longitudinally bi-impressed, nearly smooth and shining along the middle, but dull with dense minute sculpture behind, its punctation fine and irregular; the ocelli situated in small foveae in line with the back part of the eyes, these are large and moderately prominent. Thorax rather broader than long, its sides finely margined, nearly straight, just a little curvedly narrowed in front, apex subtruncate, with obtuse angles, the base straight, with almost rectangular angles: disc with a pair of large impressions which are somewhat expanded behind, their outer borders and the narrow space between them shining but not perfectly smooth: nearly all the rest of the surface is rendered dull by the dense minute sculpture; the punctures are irregularly distributed, distant on the glossy parts and apparently nearly absent at the sides. Scutellum triangular. Elytra oblong, double the length of thorax; shoulders slightly prominent and clasping the thoracic angles; apices truncate, but oblique near the sides: with fine subseriate punctures visible along the dull dense sculpture of the surface. Hind-body gradually narrowed posteriorly, closely and finely punctured, the basal 3 segments about equal and broadly marginated, 4th slightly longer, 5th subconical, the basal with a pair of rotundate pale specks.

Antennae as long as the head and thorax; their basal joint long and stout; 2nd short; 3rd elongate, nearly as long as the 4th and 5th combined; joints 6–11 loosely articulated, finely pubescent, broader than the preceding

ones; 9th and 10th transverse. Tibiae with numerous slender yellow spines along the outer edge. Tarsi, the anterior particularly, with very elongate pale hairs underneath, their 5th joint longer than all the others taken together.

Underside subopaque, nigro-fuscous, trochanters reddish; finely punctate, the intervals minutely sculptured, with distinct greyish-yellow pubescence.

Var.—Body castaneous, head nigrescent, antennae and legs testaceous. Evidently rare.

The abnormal bulk and peculiar sculpture are its distinctive features.

Length, 4–4½ mm.; breadth, 1½ mm.

Pitt Island.

Found by Mr. T. Hall. Probably common.

Group SILPHIDAE.

Choleva Latreille. Man. N.Z. Coleopt., p. 151.

55. Choleva brunneipes sp. nov.

Oval, rather elongate, gradually attenuate posteriorly, moderately convex, densely covered with very fine cinereous pubescence, subopaque; fusco-niger; the hind angles of thorax, the legs, and antennae rufo-fuscous; palpi and labrum lighter.

Head angularly dilated laterally at the middle, with large and prominent eyes there; distinctly and rather closely punctured, the intervals with minute sculpture. Thorax nearly twice as broad as long, widest near the base, curvedly narrowed anteriorly, apex incurved, with obtuse angles; base slightly bisinuate, with almost rectangular angles; its sculpture nearly similar to that of the head. Elytra scarcely as wide as thorax at the base, with broadly rounded apices; finely and closely transversely strigose; the sutural striae are well marked and somewhat flexuous near the middle, and there are several shallow, indistinct striae on each.

Legs stout; front and middle tibiae curvate, minutely bispinose at outer extremity and with longer ones at the inner, the former pair of tibiae with a notch at the inner face near the base; joints 1–3 of the anterior tarsi and the basal two of the intermediate strongly dilated. Antennae as long as head and thorax; 2nd joint rather shorter than adjoining ones; 3–6 stout, yet elongate; 6th rather shorter than 5th; 7th broader than 6th; 8th small; 9–11 densely pubescent, hardly broader than 7th.

Anterior coxae prominent and almost contiguous; sternum not carinate; 6th ventral segment obconical, as long as the 5th, and more rufescent than it is.

Near *C. lugubris*, 1911, but in it there is no sign of elytral striation beyond the suture, there is no notch in the front tibiae, and the limbs are much darker.

Male.—Length, 4½ mm.; breadth, 2 mm.

Pitt Island.

Mr. T. Hall.

Group COLYDIIDAE.

Ulonotus Erickson. Man. N.Z. Coleopt., p. 186.

60. Utonotus plagiatus sp. nov.

Oblong, subdepressed, somewhat uneven, opaque; varying from fusco-rufous to light brown; elytra paler, the sides, and on each elytron a large

median angular spot extending inwards, as well as some posterior smaller spots, fuscous; legs and antennae more or less rufescent; clothed irregularly with short suberect pale squamiform setae.

Head much smaller than thorax, with moderate antennal prominences, its sculpture granular. Thorax uneven, with a large central angular impression prolonged as a broad groove to the apex, a pair of more rounded ones near the base, and an angular fovea in front of the scutellum, with granular sculpture; it is slightly broader than long, the sides are explanate, somewhat curvate, and there is a slight sinuosity near the rectangular posterior angles, between each of these and the shoulder an evident gap occurs, the anterior angles protrude as far as the front of the eyes, there are no obvious lateral indentations. Elytra oblong, apparently punctate-striate, with several small nodosities near the top of the apical declivity, and a pair at the base; the space between each of the latter and the slightly raised shoulder appears broadly depressed.

Underside subopaque, fuscous, granulate, with a few short pale setae.

Eyes prominent, with coarse facets. Tibiae thickly setose, unarmed, straight inwardly. Antennae sparsely pubescent; their basal joint thick, cylindric; 2nd shorter and not as stout as the 1st, slender at its base; 3rd elongate; 4th rather longer than broad; 5–8 about equal: club oblong-oval, large, triarticulate.

The members of this genus are divisible into sections. The first is composed of species having the sides of the thorax lobate or indented; the second contains such as have the flattened sides of the thorax entire, or nearly so. This species belongs to the second section, and is distinguishable from the others by the oblong form, sculpture, and dark lateral mark on each elytron.

Length, 3½–4½ mm.; breadth, 1½–2 mm.

Pitt Island.

Another of Mr. Hall's discoveries.

Coxelus Latreille. Man. N.Z. Coleopt., p. 195.

61. Coxelus mucronatus sp. nov.

Opaque, elongate, irregularly clothed with suberect squamiform brassy setae, and some obscure infuscate ones; variegate, piceous, antennae and tarsi rufescent.

Head subquadrate, smaller than thorax, longitudinally impressed near each side, moderately closely covered with small granules; each of these has a minute puncture. Eyes prominent, setigerous behind. Thorax a little uneven, of equal length and breadth, base strongly bisinuate, apex medially subtruncate, with slightly prominent obtuse angles, posterior angles rectangular but not touching the shoulders; its sides setose, gently narrowed backwards, their channels well marked near the front; disc punctate-granulose, with a central longitudinal impression in front, and a pair of shorter ones near the base, where there is an angulate fovea, and in some cases a transverse linear depression. Elytra elongate-oblong, singly rounded at the base, nowhere broader than the thorax; they are closely seriate-granulate, broadly bi-impressed just before the middle, so that the suture at that part seems somewhat elevated; on the summit of the declivity, at the suture, there is a contiguous pair of small dark crests; on each there is a basal, a post-median, and an outer spot on the declivity, usually covered with yellowish setae; sometimes the derm is rufescent there.

Antennae with some very slender hairs, basal joint concealed above, 3rd about as long as 2nd but much more slender, joints 4–6 rather longer than broad, 9th obconical, broader than 7th or 8th; club abruptly enlarged, its basal joint evidently broader than the apical, which is rotundate.

Legs with more slender greyish setae than the body; tibiae flexuous; the intermediate especially, and strongly produced inwardly at the extremity, the anterior less so, posterior not distinctly mucronate.

Underside opaque, piceo-rufous, more or less closely granulate, with numerous slender elongate flavescent setae; 3rd ventral segment as long as the 2nd and more distinctly impressed in the middle; prosternum bisulcate between the coxae.

The strongly mucronate middle tibiae clearly distinguish this species. An immature specimen is almost wholly ferruginous.

Length, 4–4½ mm.; breadth, nearly 1½ mm.

Pitt Island.

Mr. T. Hall.

Pycnomerus Erickson. Man. N.Z. Coleopt., p. 208.

62. **Pycnomerus mediocris** sp. nov.

Elongate, moderately shining, piceous, elytra sometimes more rufescent, antennae and tarsi pitchy-red.

Head distinctly punctate, bi-impressed in front. Antennae pubescent, joints 4–9 transverse, terminal joint evidently narrower than the 10th. Thorax slightly longer than broad, widest near the front, gradually narrowed backwards, anterior angles somewhat prominent, the posterior rectangular but not sharply defined; disc broadly longitudinally impressed, the middle of the impression nearly smooth towards the base; its punctation moderately close and coarse. Scutellum small. Elytra wider than thorax at the base, twice its length, with obtusely prominent shoulders; they are deeply punctate-striate; the punctures are distinctly separated; only the sutural striae reach the apical margin, which is a little incrassate, elevated, and bent outwards; the inner three interstices on each elytron are rather thicker than the others; the suture is bent outwards at the base and is united to the 3rd interstice.

Underside piceous, rather coarsely punctate, each puncture with a minute yellow seta. Metasternum longitudinally impressed behind. Apical ventral segment broadly bifoveate, its basal margin and the middle nearly smooth.

This belongs to the section comprising species with moderately large eyes and a distinctly divided biarticulate club. It differs from *P. longulus* in having slightly projecting front angles and different elytral interstices, &c.

Length, 3½–4 mm.; breadth, 1–1¼ mm.

Pitt Island.

We are indebted to Mr. Hall for specimens.

Group BOTHRIDERIDAE.

Bothrideres Erickson. Man. N.Z. Coleopt., p. 207.

63. **Bothrideres paynteri** sp. nov.

Elongate, subdepressed, slightly nitid, with a few slender inconspicuous greyish setae; nigrescent, legs piceous, tarsi and antennae piceo-rufous.

Head much narrower than thorax, with prominent eyes; it is moderately coarsely punctured, more finely and closely on the forehead. Thorax of equal length and breadth, widest near the front, very gradually narrowed backwards, posterior angles acutely rectangular, the anterior rather obtusely prominent; disc nearly plane, sparingly and irregularly punctate, so as to appear almost smooth on some parts, without any well-marked fovea, its sides more closely but not as coarsely punctured. Scutellum triangular, subdepressed. Elytra with obtusely prominent shoulders, broader than the thorax, quite twice its length, widest just before the middle; on each elytron there are 2 slender minutely punctate striae near the suture, the inner is curved outwards and bordered inwardly by a carina at the base, the broad interstice between these is nearly smooth but has a short basal stria; including the suture, there are 4 costae behind, the outer pair are very slender and are prolonged to the base, the inner of these is indistinctly duplicated; between each pair of these carinae there are 2 series of fine punctures, the 3rd interstice is finely and irregularly punctured throughout.

Underside subopaque; prosternum without any tubercle, moderately coarsely and closely punctured, its flanks with a few fine punctures only; metasternum with a median groove behind, its punctation similar to that of the prosternum; basal ventral segment nearly as long as the following three combined, not closely punctured.

Antennae finely pubescent; 2nd joint bent and inserted in the notch at the hind part of the subglobular 1st; joints 3–8 quite as long as broad; 9th rather broader and obconical; 10th double the breadth of the 9th, rounded towards its base; 11th rather smaller.

Larger than its New Zealand allies, and readily distinguishable therefrom by the different sculpture and more triangular scutellum.

Length, 6–6¼ mm.; breadth, quite 2 mm.

Pitt Island.

Mr. Hall's coadjutor in forming this collection was Mr. R. E. Paynter, whose name therefore has been attached to this species.

Group DERMESTIDAE.

Trogoderma Latreille. Man. N.Z. Coleopt., p. 240.

66. Trogoderma pictulum sp. nov.

Nitid, elongate-oblong, slightly convex; unevenly clothed with distinct decumbent yellowish pubescence above, but along the sides the hairs are more infuscate and erect; derm variegate, for the most part rufo-castaneous, the middle of the base and sides of thorax of a brighter red, as are also the base, the shoulders, and other large but not sharply limited spots on the elytra.

Head dull, small, rather coarsely and closely punctured. Eyes prominent. Antennae short; 1st joint thick, reddish; joints 2–4 testaceous, 2nd stout, 3rd slender and elongate, 4th subtriangular, as long as its predecessor but broader; joints 5–11 fuscous, each in succession more prolonged inwardly, the 10th quite as long inwardly as the much thicker terminal joint. Thorax at the base twice as broad as it is long, curvedly narrowed anteriorly, the base oblique towards the sides, and at the middle somewhat prominent, so as to partly overlap the scutellum; it is not definitely granulate, but the distinct though rather fine punctures are more or less encircled with slightly raised margins. Elytra of about the same width as the thorax, thrice its length, each with a shallow oblique or curvate impression extending

inwards from the shoulder; the space in front of this slightly and obtusely elevated; there are some obsolete striae on the disc; the punctation is like that of the thorax.

According to its description, *T. scrrugerum*, 426 in the New Zealand list, must be somewhat similar, but the clothing and sculpture must be very different. I have not seen the insect itself.

Length, 5–5½ mm.; breadth, 2¼ mm.

Pitt Island.

Another of Mr. Hall's discoveries.

Group Aphodiidae.

Aphodius Illiger. Man. N.Z. Coleopt., p. 257.

67. **Aphodius sulcatissimus** sp. nov.

Parallel, oblong, moderately convex, nitid, glabrous, nigrescent, margins of head and thorax and the legs rufous, elytra sometimes slightly rufescent, tarsi and antennae fulvescent.

Head unarmed, forehead deeply medially incurved: the broad margins end abruptly just before the flat hardly discernible eyes; it is not quite as broad as the thorax; its punctation minute and distant in front, becoming closer and coarser behind. Thorax transversely quadrate, only slightly broader than long, lateral margins well developed in front, sides nearly straight, posterior angles rounded; the whole surface finely and distantly punctured, the basal half of the disc, however, has numerous coarse scattered punctures. Scutellum narrow. Elytra oblong, with acutely prominent spiniform shoulders; apices broadly rounded; each elytron with 6 deep dorsal striae, the distinct punctures at the bottom of these are evidently separated from one another, the 3 external ones are not so deep; interstices minutely punctate, those near the suture are moderately broad, the others are narrow and almost cariniform.

Anterior tibiae tridentate externally; the terminal spur of the intermediate and posterior equals in length the basal two joints together of the tarsi; the second, or inner, spur is shorter. Pygidium vertical, subconical, with a median punctiform fovea at its base.

Underside nitid, blackish; prosternum closely, the metasternum and abdomen rather finely and distantly, punctured; the base of segments 2–5 with a transverse series of very coarse punctures, so as to appear crenulate; the basal segment is subcarinate in the middle.

The unmistakably spiniform humeral angles, profound elytral striae, and subcarinate outer interstices separate this from all the New Zealand species except *A. fortipes*, 1721; in it the sculpture of the head is different, the shoulders are less prominent, and the elytral interstices are rather broader.

Length, 3½ mm.; breadth, 1⅓ mm.

Pitt Island.

Five examples in Mr. Hall's collection.

Group Melyridae.

Dasytes Paykull. Man. N.Z. Coleopt., p. 329.

70. **Dasytes pittensis** sp. nov.

Narrow, elongate, dilated posteriorly, subopaque; pubescence scanty, minute, and greyish; dark blue, legs and antennae piceous, 2nd joint of these latter somewhat rufescent.

Head about as broad as thorax, finely and distantly punctured, the intervals minutely and densely sculptured, broadly bi-impressed between the moderately prominent eyes. Antennae quite as long as the head and thorax; basal joint stout, obconical; 2nd shorter than 3rd; joints 4–10 sub-serrate, each longer than broad; 11th elongate-oval. Thorax moderately dilated laterally near the middle, about as long as broad, the spaces between the rather fine distant punctures densely and minutely sculptured; in some examples there is a slender stria along the middle, in all there is a shallow impression near the base. Scutellum broad, medially grooved. Elytra as broad as thorax at the base, wider behind the middle, rather finely punctured, interstices slightly rugose and minutely sculptured.

Of about the same size as the New Zealand *D. oreocharis*, 2036, of a darker hue, differently sculptured, and the thorax without perceptible lateral margins.

Length, 5 mm.; breadth, $1\frac{1}{2}$–2 mm.

Pitt Island.

Evidently the common species, though probably not the only one. Mr. T. Hall.

Group Otiorhynchidae.

Thotmus gen. nov.

Rostrum not as broad as the head and not distinctly marked off from it, a third shorter than the thorax. Scrobes subapical, deep, broad, and quite open above, abruptly bent downwards, narrowed, and not extending more than half-way towards the eyes. Scape implanted near the apex and just attaining the back of the eye, considerably yet gradually incrassate. Funiculus 7-articulate; its basal two joints almost equal, their length only about double the breadth; joints 4–6 thick, each much narrowed at the base; 7th more transverse, distinctly separated from the club and preceding joint. Club conical, indistinctly quadri-articulate. Eyes rather small, not prominent, distant from the thorax, more so from each other, transversely oval, subtruncate in front. Thorax without definite ocular lobes, base truncate, rounded laterally, it is transversal. Scutellum large. Elytra oblong-oval, the shoulders curvedly narrowed; apices, conjointly, broadly rounded.

Femora stout, simple. Tibiae nearly straight, dilated at the extremity, posterior corbels thickly ciliate and cavernous. Tarsi with setose soles, their basal two joints subtriangular, 3rd moderately expanded and bilobed.

Prosternum deeply incurved in front. Metasternum moderate. Basal ventral segment, in the middle, nearly twice the length of the 2nd, broadly rounded between the coxae, the hind suture medially sinuate, 2nd less than double the length of 3rd or 4th. Epipleurae linear throughout. Anterior coxae contiguous, posterior widely distant.

In *Cecyropa* the eyes are placed at or near to the thoracic margin, the rostrum is very short, but the scape is elongate and reaches backwards to beyond the apex of the thorax, the front coxae are distinctly separated, and the anterior tibiae are furnished with a lobelike prolongation which usually covers the basal tarsal joint, this lobe is lacking in *Thotmus*.

The presence of supplementary mandibles shows without doubt that this genus must be located in the *Otiorhynchidae*, along with *Cecyropa*, which was placed by Pascoe in the *Rhyparosomidae*.

75. **Thotmus halli** sp. nov.

Subovate, moderately convex, without superficial inequalities, derm subopaque, pale rufo-castaneous, covered with thin depressed inconspicuous obscure greyish squamae, and also bearing numerous suberect grey setae.

Rostrum with a median linear impression. Head moderately convex. Thorax a third broader than long, apex feebly emarginate, widest near the middle, rather more abruptly narrowed behind than in front, on a carefully denuded spot finely and distantly punctured. Elytra more than double the length of the thorax, nearly vertical behind; each, at the base, oblique towards the suture, and consequently not closely applied to the thorax; they are rather finely punctate-striate. Legs thickly clothed with grey setae.

Underside reddish-chestnut, with grey setae.

Length (rostrum inclusive), 13 mm.; breadth, $6\frac{1}{2}$ mm.

Pitt Island.

Named in honour of its discoverer, Mr. T. Hall. The specimen is unique and somewhat immature; perfect examples probably will be darker. It is, I have no doubt, an inhabitant of the sea-shore, where it should be sought for.

Platyomida White. Man. N.Z. Coleopt., p. 441.

76. **Platyomida versicolor** sp. nov.

Subopaque, nigrescent; covered with depressed tawny squamae, which, however, are intermingled with a few metallic cupreous and viridescent ones; these are most apparent when the insect has been brushed with benzine; there are also some obscure yellowish setae on the elevated and posterior parts of the elytra; antennae and tarsi piceo-rufous.

Rostrum nearly as long as thorax, with a median carina separating the broad longitudinal grooves and terminating in the interocular fovea. Thorax as broad as it is long, slightly broader before the middle than elsewhere, base and apex subtruncate; the surface somewhat uneven, with slightly rugose tubercular sculpture and a rather broad irregular channel along the middle. Scutellum normal. Elytra broader than thorax at the base, wider near the middle, a good deal narrowed posteriorly; disc nearly plane, striate-punctate, 3rd and 5th interstices slightly nodiform at the top of the posterior declivity, in the female slightly and unevenly elevated throughout.

Underside blackish, the squamae of a more metallic lustre and more brightly coloured than those above. Prosternum incurved. Basal ventral segment evidently longer than 2nd, subtruncate between the coxae; 5th as long as the 3rd and 4th combined.

Scape minutely squamose, gradually thickened, attaining the back of the eye; 2nd joint of funiculus as long as the basal; club minutely pubescent, almost as long as joints 4–7 of the funiculus taken together.

Ocular lobes feebly developed. Posterior corbels with duplicate ciliae and a narrow external truncature.

Male.—Elytra elongate-oviform, and only slightly broader than thorax at the base; legs longer, more slender and flexuous. When compared with the same sex of the common *P. binodes*, 776, of New Zealand, the

more elongate outline, nearly level and regularly punctured elytral disc, and the vestiture, are seen to be very different.

Length: Male (rostrum inclusive). 13 mm.; breadth, 4½ mm. Female: 14 × 6 mm.

Pitt Island.

Two damaged specimens from Mr. T. Hall's collection.

Group Rhyparosomidae.

Phrynixus Pascoe. Man. N.Z. Coleopt., p. 132.

77. **Phrynixus asper** sp. nov.

Opaque, convex, subovate, piceo-fuscous, encrusted with light-brown sappy matter; rostrum and tarsi piceo-rufous; body tuberculate, irregularly clothed with somewhat tawny, on some parts curled, squamiform setae.

Rostrum arched, rather shorter than thorax, indistinctly tricarinate in front, with a setigerous tubercle before the eyes and a pair of smaller ones close to the antennae. Thorax apparently oblong, actually, including lateral tubercles, of equal length and breadth; with a pair of apical tubercles and a slight ridge between them, trituberculate across the middle, uneven and medially depressed behind, a few coarse punctures and short rugae may be seen, its sides also are uneven. Elytra about twice the length of thorax, at the middle nearly twice as broad, posterior declivity almost vertical, their shoulders porrect and crested with curled setae, the median basal depression with ridged lateral borders; on each elytron, when properly cleaned, a dozen crested tubercles can be seen on the disc and sides, none are very large; there are also a few coarse punctures and small black granules; the posterior declivity is substriate-punctate.

Legs moderately elongate, bearing somewhat flavescent setae; tibiae unarmed; tarsi minutely setose above, basal two joints short, 3rd hardly at all dilated, excavate but not lobed.

Scape inserted in foveiform scrobes at or just behind the middle, flexuous, slender, but clavate at the extremity; it is setose and attains the back of the eye. Funiculus rather densely clothed, and bearing also some elongate setae; 2nd joint not quite the length of the 1st, joints 3–6 short and somewhat moniliform, 7th obconical and not very much smaller than the ovate club. Eyes subdepressed, about equidistant from the thorax and each other, subrotundate or obliquely oval. No scutellum.

Like the New Zealand *P. astutus*, 759, differing principally in the trituberculate rostrum and the larger 7th joint of the funiculus.

Length (rostrum exclusive), 4½ mm.; breadth, 2½ mm.

Pitt Island.

Mr. T. Hall. Rare.

Group Cylindrorhinidae.

Hadramphus gen. nov.

Rostrum slightly dilated at apex, nearly as long as thorax, very gradually expanded behind. Head short, convex, not at all abruptly broader than the rostrum. Scrobes visible above near the extremity, deep, rectilinear, and extending to the front and lower part of the eyes. Scape inserted near the apex, straight, hardly attaining the eye. Funiculus 7-articulate;

basal joint evidently longer than 2nd, which is not twice the length of the 3rd; joints 4–7 rather longer than broad. Club ovate, not large, tri-articulate, intermediate joint very short. Eyes truncate in front, their length from above downwards double that of the longitudinal diameter; they are subdepressed and widely distant above. Thorax with well-developed ocular lobes, these during repose cover a third of the eyes; base and apex subtruncate; it is rather broader than long, and at each side is obviously medially tuberculate. Scutellum distinct. Elytra oblong-oval, only slighter wider than thorax at the base, apices broadly rounded, their sides spinose.

Femora elongate, somewhat clavate, grooved underneath near the extremity. Tibiae a little flexuous, each armed at the apex with a well-developed spur, which begins outwardly as a ridge, extends along the bottom, and projects inwardly; just above each spur, on the inside, there is a pair of outstanding tufts of setae; the posterior are densely fringed with ferruginous setae but are not cavernous. Tarsi hairy above, their basal joint rather slender at the base and nearly twice the length of the 2nd, 3rd slightly dilated and bilobed; their soles densely brushlike but quite glabrous along the middle.

Prosternum deeply incurved in front. Anterior coxae contiguous, intermediate slightly separated, the posterior more widely. Metasternum very short. Abdomen elongate; 1st segment longer than 2nd, strongly curved between the coxae, medially sinuate behind; 3rd and 4th, singly, nearly as long as 2nd; 5th truncate, and with a broad tuft at each side, at the apex; 6th semicircular. Epipleurae linear. Mentum small, subquadrate. Palpi short. Mandibles indistinctly trifid at apex.

The armature of the tibiae, though somewhat similar to that of the European *Molytes*, more closely resembles that of *Lyperobius*. The ocular lobes are more strongly developed. and the tarsal vestiture differs. In facies these genera are utterly unlike *Hadramphus*, a glance at the sides of the hind-body being sufficient for immediate separation. It should be placed after *Phaedropholus*, but before *Lyperobius*.

78. Hadramphus spinipennis sp. nov.

Subovate, opaque, fuscous, antennae and tarsi piceous; covered with hairlike tawny squamae, usually more infuscate on the dorsum, and in some cases there is a pale streak along each side and the middle of the thorax.

Rostrum rugose-punctate and thinly setose near the extremity. with a fine median carina, and coarse shallow sculpture; its clothing is disposed transversely; it is very gradually expanded towards the base. Thorax medially dilated and with a prominent tubercle at each side; disc uneven, the borders of the irregular impression along the middle more or less elevated, most distinctly raised near the base; there are no frontal crests or nodosities, and no punctures are discernible, the sculpture consisting apparently of irregular flattened granules. Elytra more than twice the length of thorax, quadri-spinose at each side; the dorsum with indefinite serial punctures near the suture, in some examples substriate behind, the somewhat inflexed sides are distinctly seriate-punctate; on the 3rd interstice of each elytron there is an elongate basal elevation and 2 or 4 tubercles, the largest being placed behind the middle; between the last and the apex there are 3 or 4 smaller ones; on the 5th interstice there are usually

4 tubercles, the hindmost being on top of the declivity; alongside the suture there is generally a series of much smaller nodosities.

Underside nigrescent, clothed with depressed elongate flavescent setae.

The superficial sculpture of the hind-body is provokingly irregular, not only in different specimens, but on the elytra of the same individual, so that a precise description cannot be given. The lateral spines are sometimes equidistant and hooklike, but the number is constant. Notwithstanding these discrepancies there can be no difficulty in identifying the insect.

Length (rostrum exclusive), 21–22 mm.; breadth, 10 mm.

Pitt Island.

Found by Mr. Hall.

Group Cryptorhynchidae.

Kentraulax Broun. Ann. Mag. Nat. Hist., ser. 8, vol. 4, p. 156.

83. **Kentraulax flavisetosus** sp. nov.

Robust, nitid, nigrescent, antennae and tarsi rufo-piceous; scantily clad with very fine yellow setae, but towards the extremity of the elytra the setae are more numerous, squamiform, and conspicuous.

Rostrum a third shorter than thorax, quite half the width of the head, moderately closely punctate, with a groove along the middle. Head rounded towards the front, broadly impressed between the eyes. Thorax a third broader than long, its sides curvedly narrowed towards the abruptly contracted apical portion, subtruncate or slightly emarginate in front, the base bisinuate; rather coarsely and closely punctured, with a nearly smooth linear space along the middle terminating in an elongate basal depression. Scutellum smooth. Elytra double the length of the thorax, slightly wider than it is at the base, apices subtruncate; they are deeply punctate-striate, interstices broad, closely and finely granulate and rugose.

Underside shining, black, with slender yellow setae. Metasternum and abdomen coarsely punctured, the former angularly depressed behind, basal ventral segment with a shallow rotundate impression behind the middle, the second medially subcarinate.

Male.—Rostrum with a well-marked dilatation just below the point of antennal insertion, so that the frontal portion appears expanded when looked at from above. Scape short and very thick, not reaching the eye. Funiculus stout, 7-articulate, 2nd joint as long as the short 1st, joints 3–7 short, compact, expanded successively, so that the 7th is fully as broad as the triarticulate club. Prosternal canal with a conspicuous spiniform process at each side in front.

Female.—Rostral canal angulate. Club more ovate. Rostrum less dilated in front.

Scape medially inserted. Eyes subtruncate in front. Scutellum triangular. Posterior tibiae, as well as the intermediate, with a median dentiform angulation, and another at the extremity.

The typical species of *Psepholax* can be at once distinguished by the moderately elongate scape being inserted near the apex.

K. murina, 864, is differentiated by its thoracic carina and the more abundant and scalelike vestiture above and below.

Length (rostrum exclusive), 10–11 mm.: breadth, 5–5½ mm.

Pitt Island.

Several in Mr. Hall's collection.

Acalles Schoenherr. Man. N.Z. Coleopt., p. 488.

87. **Acalles lineirostris** sp. nov.

Convex, subovate, derm piceo-rufous, tarsi and antennae pale ferruginous; thickly covered with rather coarse variegated squamae, many of which are erect, their predominating colour is yellowish-brown; on the apex of the thorax there is a pair of small pallid tufts, and at the middle of its base an almost white longitudinal streak, on the elytral disc and the legs a few whitish scales are seen; blackish ones extend across the thoracic base, cover the shoulders and much of the legs, and form spots on the hind-body.

Rostrum rufescent, with linear sculpture and coarse punctures, it about equals the thorax in length, is subparallel, and slightly arched. Thorax abruptly contracted in front, a little broader than long, its sides nearly straight behind; it is closely and distinctly punctured; the erect scales in front of the broad basal portion do not form definite crests. Scutellum absent or indistinct. Elytra subcordate, with oblique shoulders, so that the base does not exceed that of the thorax in width; in the middle they are nearly twice as broad; the apical declivity is almost vertical; they are seemingly striate-punctate; on the 3rd interstice of each elytron there is a distinct crest on the summit of the declivity, and 3 or 4 on the 5th, the hindmost being placed half-way down the declivity; there are others near the side; these small crests do not exactly correspond, though they may do so in fresh unabraded specimens—at any rate, they cause the surface to be somewhat irregularly uneven.

Scape rather elongate, moderately slender, slightly flexuous, incrassate near the extremity; it is inserted just before the middle and attains the front of the eye. Funiculus with slender grey hairs, elongate; 2nd joint about as long as but more slender than the 1st; 3–6 consecutively slightly shortened and widened; 7th almost as broad as the base of the club, which is densely pubescent, triarticulate, and subovate; its basal joint is half the whole length. Legs stout and elongate. Tarsi hairy above, their penultimate joint moderately expanded and bilobed.

In bulk and general aspect this approaches the New Zealand *A. scitus*, 878, but the marks are different; the thorax in 878 is much less contracted anteriorly and the tarsi are more slender.

Length (rostrum exclusive), $3\frac{1}{2}$ mm.; breadth, nearly 2 mm.

Pitt Island.

The single specimen at my disposal was found by Mr. Hall.

88. **Acalles subcarinatus** sp. nov.

Subovate, moderately convex, not asperate, subopaque, rufo-piceous, covered with tenacious greyish sappy matter, the squamosity obscure greyish or pale tawny and inconspicuous; antennae and tarsi dark ferruginous.

Rostrum arched, subparallel, about a third shorter than thorax, with shallow coarse punctures which become much finer near the extremity, along the middle there is a slender carina. Head immersed up to the nearly flat eyes. Thorax a good deal contracted in front, a third broader than long, the sides slightly curvedly narrowed behind, the base depressed and feebly medially incurved; disc with a smooth slightly raised carina along the middle, its punctation moderately coarse and close, each puncture has a pale-tawny scale imbedded in it. Elytra bisinuate at the base, rather

broader than thorax, their obtusely porrect humeral angles clasp the thorax, the sides are a little uneven, rounded, and rather abruptly narrowed posteriorly, the declivity is nearly perpendicular; they are very coarsely seriate-punctate, much more finely behind; there is a slight elevation each side of the scutellum, and there are 4 small crests on top of the declivity which are absent in my specimen, the male.

Scape implanted at or just before the middle, reaching the eye, slightly flexuous, gradually thickened, glabrous. Funiculus sparingly and finely setose, 2nd joint of about the same length as the basal, joints 3–7 successively thickened, so that the last is as broad as the subovate club, the basal joint of which is longer than the following two combined.

Femora long and stout, subangulate and minutely dentate in the male, less so, the anterior not at all, in the female. Legs sparsely setose. Tarsi glabrous above in the male, with yellow hairs in the other sex, their 3rd joint moderately dilated and lobate. Scutellum present, tilted forwards. In the female the rostrum is more finely punctate.

The solitary mounted specimen in my possession does not permit a thorough examination of the sternal structure; had another been available this species, together with 2942 and 2951, would have been placed in a new genus, the more salient characteristics being the presence of the scutellum, porrect humeral angles, and indefinite femoral armature.

Length (rostrum exclusive), 4½ mm.; breadth, 2½ mm.

Pitt Island.

In Mr. Hall's collection.

Xenacalles Broun gen. nov.

89. Xenacalles squamiventris sp. nov.

Opaque, piceous, covered with pale-brown or tawny depressed squamae and erect occasionally greyish ones, which sometimes form a pair of small crests on the suture at the summit of the posterior declivity; just in advance of these there is a large transverse somewhat diamond-shaped fuscous spot: rostrum piceous or reddish, antennae and tarsi ferruginous or fulvescent.

Rostrum as long as thorax, finely punctate, squamose near the base. Scape medially inserted. Thorax slightly longer than broad, gradually narrowed anteriorly, not constricted in front, rounded and bearing erect setiform squamae there, its punctation concealed by the scales, some of which are fuscous. Scutellum distinct. Elytra slightly broader than thorax at the base, rather wider before the middle, evidently narrowed posteriorly, seemingly punctate-striate; the striae more distinct along the declivity than on the disc. Legs elongate, thickly squamose; tibiae usually fuscous near the middle.

Underside densely covered with tawny scales, and with some almost white ones on the basal two ventral segments and basal half of the femora; the 3rd and 4th segments, singly, more than half the length of the 2nd.

The following characters differentiate this species from *Acalles*: Scutellum distinct. Pectoral canal extending to front of metasternum, deep there. Tarsi with hairy instead of spongelike soles. Metasternum not longer than 2nd abdominal segment. Body elongate, subfusiform.

The half-dozen alcoholic specimens were difficult to manipulate. In trying to get out the rostrum and antennae the whole thorax would persist in parting from the hind-body, &c.

Length (rostrum exclusive), 3 mm.; breadth, 1½ mm.

Pitt Island.

Mr. Hall.

GROUP COSSONIDAE.

Pentarthrum Wollaston. Man. N.Z. Coleopt., p. 508.

93. Pentarthrum dissimilum sp. nov.

Subglabrous, having only a few minute grey hairs near the apices of the elytra, fusiform-cylindric, shining, rufous, elytra pale rufo-castaneous.

Rostrum parallel, broad, half the length of thorax, longitudinally impressed, distinctly but not closely punctate. Occiput smooth. Thorax of almost equal length and breadth, widest and moderately rounded behind the middle, gradually narrowed towards the abrupt but not deep frontal stricture, it is moderately coarsely but not closely punctured. Scutellum small, yet distinct. Elytra slightly wider than thorax at the base, truncate there, twice its length, narrowed near the extremity; they are punctate-striate, the punctures are well marked, the striae most distinctly impressed behind the middle; interstices with fine serial punctures, hardly at all rugose, those nearest the suture somewhat thickened towards the extremity.

Scape medially inserted, straight, gradually thickened; 2nd joint of funiculus nearly the length of the 1st; club rather narrow.

Underside nitid, castaneo-rufous, sparingly and finely pubescent, distinctly but not very closely punctate, basal ventral segment broadly impressed and not much longer than the 2nd.

When compared with the male of *P. zealandicum*, 903, the eyes appear less prominent, the rostrum more finely and less rugosely punctured, and the elytra more distinctly striate, with more definite and not at all crenate punctures.

Male.—Length (rostrum inclusive), 4 mm.; breadth, quite 1 mm.

Pitt Island.

Mr. T. Hall.

94. Pentarthrum auripilum sp. nov.

Fusiform-cylindric, subnitid; rufo-piceous, tarsi and antennae piceo-rufous, club paler; thinly covered with elongate golden hairs, which on the thorax are disposed transversely.

Rostrum quite half the length of thorax, not as broad as the head, parallel, rather flat, broadly impressed along the middle; rather closely, coarsely, and somewhat rugosely punctured, more finely near the apex; pubescence distinct. Head similarly sculptured in front, the occiput nearly smooth. Thorax slightly longer than broad, widest behind the middle, rounded there, curvedly narrowed towards the abrupt apical constriction, and with an evident gap between its widest part and each shoulder; disc moderately coarsely but not very closely punctured. Scutellum triangular, rather small. Elytra subtruncate, and rather wider than thorax, at the base, nearly twice its length, subcylindrical, narrowed behind the posterior femora; distinctly striate-punctate, interstices with well-marked serial punctures and somewhat rugose.

Scape straight, inserted immediately before the middle, gradually incrassate, attaining the centre of the eye; 2nd joint of funiculus as long as the 1st, 3–5 rather broader than long; club indistinctly articulated and hardly broader than the preceding joint, but appearing more ovate when examined in another way. Legs normal, penultimate tarsal joint slightly dilated but not lobed.

Female.—Rostrum little more than half as thick as that of the male, cylindric, shining, and much more finely punctate. Scape more slender, implanted behind the middle. Thorax more gradually narrowed anteriorly and less constricted in front. The vestiture less obvious.

The pubescence causes this species to seem strange in *Pentarthrum;* still, I fail to detect any good differentiating characters.

Length (rostrum inclusive), 4 mm.; breadth, 1 mm.

Pitt Island.

Mr. T. Hall.

Agastegnus Broun. Man. N.Z. Coleopt., p. 805.

96. **Agastegnus ornatus** sp. nov.

Subdepressed, elongate, nitid; sparingly clothed with slender yellowish pubescence; elytra testaceous, with an irregular broad pitchy-brown fascia on each, extending obliquely forwards from the hind thigh to before the middle but not quite reaching the suture, and a smaller dark spot behind but distant from the side; the head, front of thorax, and the club somewhat piceous; the rest of the body, legs, and antennae bright chestnut-red.

Rostrum rather shorter than thorax, a little narrowed towards the base, moderately finely punctate. Head narrowed anteriorly, more distinctly and closely punctured than the rostrum, the occiput smooth and shining. Eyes subrotundate, slightly prominent. Thorax abruptly constricted near the apex, about as long as broad, the sides behind the constriction strongly rounded; disc rather flat, with a smooth linear space along the middle terminating in a well-marked basal fovea, its punctation distinct, closer at the sides, its apex nearly smooth. Scutellum smooth. Elytra rather broader than thorax at the base, nearly parallel-sided, gradually narrowed posteriorly; they are distinctly striate; the punctation of the striae, however, is not sharply defined, and appears crenate on some parts; interstices finely punctured and rugose, the 3rd and 5th somewhat elevated, the former near the extremity, the latter behind the dark median fasciae.

Underside shining, piceous, with some slender grey setae, the prosternum with distinct yellow ones, and rather coarsely punctate. The metasternum elongate, more finely punctured on the middle than at the sides; behind each of the intermediate coxae there is a well-marked fovea, and along the hinder half a median groove. Basal ventral segment nearly twice as long as the 2nd, strongly rounded between the coxae, broadly impressed in the middle, distantly and distinctly punctured; 3rd and 4th short, with deep sutures; 5th with a very obvious median fovea. Anterior coxae nearly as far apart as the intermediate pair.

Legs moderately elongate; tibiae with well-developed apical hooks; tarsi elongate, their 3rd joint slightly dilated, excavate above, but not bilobed. Antennae medially inserted, 2nd joint of the funiculus as long as the 1st, joints 3–5 transverse; club oblong-oval, densely pubescent, obsoletely articulated.

A brightly coloured species which, on account of the unusually large smooth occiput, should be placed in proximity to the New Zealand *A. coloratus*, 1630.

Length (rostrum inclusive), 3–3½ mm.; breadth, ⅔–1 mm.

Pitt Island.

We are indebted to Mr. T. Hall for the discovery of this species.

Obs.—In one example the dark marks on the elytra coalesce, and the thorax is more or less infuscate.

Group ANTHRIBIDAE.

Anthribus Geoffroy. Man. N.Z. Coleopt., p. 545.

100. Anthribus cristatellus sp. nov.

Nitid, variegate; fuscous, mandibles rufous, antennae fusco-testaceous; legs castaneous, the tibiae with a dark spot below the middle, a pale spot above, and another near the extremity; vestiture hairlike, unevenly distributed, pale tawny and obscure reddish, the pale setae concentrated and forming a large spot near the front angles of the thorax, each elytron tricristate near the suture.

Rostrum, mandibles exclusive, a third of the length of thorax, broad and flat, medially emarginate in front, slightly narrowed towards the eyes, rather closely punctate, usually rufescent. Thorax of about equal length and breadth, moderately narrowed before the middle, slightly rounded behind, the truncate apex with deflexed angles, its punctation moderately coarse and close; the carina is very near the base, truncate in the middle, rounded towards the sides, without forming the least trace of posterior angles, and prolonged half-way along each side. Scutellum minute, merely a grey speck. Elytra only a little longer than thorax, of about the same width as it is at the base, truncate there, gently curvedly narrowed posteriorly, with broadly rounded subtruncate apices, leaving the broad vertical pygidium exposed; they are striate-punctate.

Antennae rather shorter than the head and thorax, inserted below the sides of the rostrum nearly midway between its apex and the eyes; their 2nd joint rather longer than the uncovered portion of the 1st, joints 3–8 gradually yet only slightly shortened successively, clavate at the extremity, the 8th evidently longer than broad; club densely pubescent, of about the same length as joints 6–8, basal joint triangular, the terminal ovate or rotundate.

Underside piceo-fuscous, very finely pubescent. Metasternum short. Basal ventral segment, in the middle, almost as long as the 2nd and 3rd united, obtusely angulate between the coxae, 5th reddish, longitudinally concave. Prosternum moderately coarsely punctate. Anterior coxae slightly separated.

Eyes free from thorax, widely distant from each other, moderately prominent, with distinct facets, obliquely oval, entire. Tarsi narrow, their 3rd joint as long as the 2nd, with slender lobes.

This must be located in proximity to the New Zealand *A. lewisi*, 2988. The thoracic carina is not exactly similar, being a little closer to the base, with obsolete broadly rounded posterior angles. Some specimens are more dully coloured and less variegated.

Length (rostrum inclusive), 4½–5 mm.; breadth, 1½ mm.

Pitt Island.

Several specimens in Mr. Hall's collection.

101. Anthribus propinquus sp. nov.

Castaneous, shining, with irregular fuscous marks, sometimes having an indefinite fascia behind the middle of the elytra; legs and antennae nearly concolorous; pubescence greyish-yellow, usually scanty and unequally distributed, in some specimens rather dense towards the hinder part of the elytra.

Rostrum subquadrate, narrower than the head, and, excluding the mandibles, barely half the length of the thorax; it is coarsely, closely, and rugosely punctured. Thorax widest between the middle and base, gradually narrowed anteriorly, obliquely towards the base, closely punctate; its carina, in the middle, is slightly curved and separated by a short distance only, though quite distinctly, from the elytra; it is gently curved forwards and forms an obtuse angle at each side, where it extends nearly half-way towards the front, becoming gradually indistinct, the space between the obtuse angle and the base is thrice as great as at the middle. Scutellum small. Elytra striate-punctate, the striae beyond the sutural ones become indistinct behind the middle, interposed between the suture and first stria, at the base of each elytron, there is a short groove; they are oblong-oval, fully double the length of the thorax, with subtruncate apices. Pygidium subquadrate, pubescent.

Antennae longer than the head and thorax, 2nd joint obviously shorter than the elongate 3rd but longer than the exposed portion of the 1st, joints 3–8 elongate, each becoming a little shorter than its predecessor; club infuscate, densely pubescent, its basal joint triangular and distinctly longer than the intermediate, the terminal conical.

Eyes almost contiguous to the thorax, widely separated above, large and prominent, subrotundate or broadly longitudinally oval, subtruncate but not at all emarginate in front. Tarsi moderate, basal joint as long as 2nd and 3rd taken together, the 3rd with narrow lobes.

Underside castaneous, distinctly pubescent; penultimate ventral segment incurved at apex and, in the middle, much shorter than the 5th. Anterior coxae almost contiguous.

Almost congeneric with *A. vates*, 967, with longer antennae, the thoracic carina more rounded and consequently forming more obtuse angles, and between these and the shoulders the gaps are more evident.

Length (rostrum inclusive), 5½–6 mm.; breadth, 2–2¼ mm.

Pitt Island.

Nearly a dozen individuals secured by Mr. T. Hall.

102. Anthribus pilicornis sp. nov.

Minute, nitid; testaceous, head and rostrum dark, each elytron with a large median fuscous spot which is bifid in front, and unites with its fellow of the other elytron, the suture behind each spot is also infuscate; pubescence scanty, greyish, and suberect; antennae with a few slender but elongate outstanding setae.

Rostrum transversely quadrate, closely sculptured. Head short, immersed nearly to the eyes, distinctly punctate. Thorax nearly as large as the hind-body, its sides almost regularly rounded, gradually narrowed anteriorly, rather more abruptly near the base, the apex also curvate; disc distinctly and moderately closely punctured, the intervals minutely sculptured; the carina is thin, quite straight, contiguous to the elytra, and forms the basal margin, it extends downwards to the anterior coxae

without forming posterior angles, there are no lateral margins, but the pale upper surface is marked off at the sides by the dark-fuscous lower portion. Scutellum obsolete or entirely absent. Elytra shaped like the thorax, but little larger, the straight well-developed basal margin is continued along the rounded shoulders and sides, apices subtruncate; they are seriate-punctate, with slight sutural striae.

Antennae inserted in sulciform cavities, which are prolonged downwards, immediately in front of the eyes; they are as long as the head and thorax, the basal 2 joints are subpyriform, joints 3-7 are about equally elongate and a little incrassate at the extremity, 8th subtriangular, rather shorter than 7th; club laxly articulated, minutely pubescent, and bearing also some setae like those on the preceding joints, the terminal conical.

Eyes entire, their greatest bulk from above downwards. Tarsi moderate, their 3rd joint with narrow lobes.

Underside dark fuscous, except along the middle of the abdomen, which is testaceous. Sternum more coarsely punctured than the ventral segments; the spaces between the punctures are minutely sculptured; the pubescence is indistinct.

In size and coloration this somewhat resembles *Dysnocryptus testaceus*, 2217, but the thoracic carina and other structural details are materially different. It is, I have no doubt, the exponent of a new genus.

Length (rostrum exclusive), 2 mm.; breadth, 1¼ mm.

Pitt Island.

Two individuals only were found in Mr. Hall's collection.

Group LAMIIDÆ.

Somatidia Thomson. Man. N.Z. Coleopt., p. 600.

103. Somatidia waitei sp. nov.

Elongate, slightly convex; the sides of thorax and of the elytra from the base to beyond the middle thighs, and also an irregular fascia behind the posterior femora which is more or less interruptedly prolonged along the suture to the apical scutiform mark, fusco-piceous; antennae, femora, and middle of elytra rufo-castaneous; tarsi and most part of tibiae testaceous; pubesence flavescent, unevenly distributed, almost entirely absent from the dark areas, the erect setae slender, principally yellowish.

Head distinctly sulcate along the middle. Thorax widest near the front, narrowed backwards so as to be of the same width as the elytra at the base, it is slightly transverse, coarsely and moderately closely punctured. Scutellum triangular, usually concealed by the pubescence. Elytra oviform, very elongate, nearly thrice the length of the thorax, disc subdepressed, very distantly and irregularly punctate.

Antennae with fine yellowish-grey pubescence and numerous longer hairs, they do not reach the extremity of the body, 3rd joint about twice the length of 4th.

The entire absence of crests at once removes it from *S. antarctica* and its immediate allies. It may be readily separated from 2582 by the elongated and somewhat flattened elytra, and by the transverse fascia being situated behind instead of being in line with the posterior femora, &c.

Length, 5½–6½ mm.; breadth, 2½–3 mm.

Pitt Island.

Dedicated to Mr. Edgar R. Waite, Curator of the Canterbury Museum, in recognition of his services in inducing Mr. T. Hall to form the collection which is dealt with in this memoir.

104. **Somatidia vicina** sp. nov.

Cupreo-fuscous, nitid; femora, knees, and a spot near the extremity of tibiae rufo-fuscous, remainder of tibiae and the tarsi testaceous; antennae fusco-rufous but becoming paler towards the extremity, they bear greyish pubescence and numerous longer hairs; the vestiture of the body is slender, pale brassy or greyish, unequally distributed, usually somewhat concentrated along the middle of the thorax, on the elytra so disposed as to leave nearly bare the humeral region, middle of the disc, a transverse space on the hinder part, and the middle of the posterior declivity; the erect setae are slender and vary from grey to yellow.

Thorax slightly broader than long, its sides strongly rounded for two-thirds of the length, a good deal and somewhat obliquely narrowed towards the base; it is rather coarsely, irregularly, but not at all closely punctured. Elytra of the same width as thorax at the base, widest near the middle, elongate-oval, convex, with a few scattered punctures.

Antennae stout, reaching backwards to the summit of posterior declivity, their 3rd joint quite double the length of the 4th, which is not appreciably shorter than the 5th.

Male.—Underside fuscous, with distinct greyish pubescence and slightly rugose sculpture; basal ventral segment, in the middle, nearly as long as 2–4 combined, distinctly margined and angulate between the coxae; 5th fulvescent, finely margined and medially sinuate behind; supplementary segment visible. The body more convex, rather narrower, thorax more regularly rounded and oviform than the female.

S. ptinoides, 1051, the nearest ally, has the thorax closely punctured. This is not the case in *S. vicina*.

Length, $3\frac{1}{2}$–4 mm.; breadth, $1\frac{1}{2}$ mm.

Pitt Island.

Several specimens in Mr. Hall's collection.

Group Coccinellidae.

Scymnus Kugelann. Man. N.Z. Coleopt., p. 645.

106. **Scymnus macrostictus** sp. nov.

Convex, oviform, nitid, with numerous suberect slender greyish setae; rufo-fuscous; legs, antennae, and palpi testaceous; each elytron bimaculate, the spots very large, occupying about half of the whole surface, and more or less fulvescent.

Head immersed up to the eyes, rather finely and distantly punctate. Thorax twice as broad as long, apex widely but not deeply incurved, with obtuse angles; the sides regularly rounded and slightly explanate, with distinct margins, posterior angles rectangular, base medially curvate and slightly sinuate towards the sides; the surface rather finely, yet quite perceptibly, but not closely punctured. Scutellum triangular. Elytra closely applied to thorax at the base, of about the same width there, thrice its length, their punctation coarser than that of the thorax.

Antennae with the 2nd joint small, distinctly marked off from the thicker basal, 3rd elongate, joints 4–7 rather longer than broad, 8th at its apex

almost as broad as the base of the 9th; club rather elongate, compact, triarticulate.

Eyes moderately large, entire. Maxillary palpi with subsecuriform terminal joints. Claws subdentate near the base.

Underside distantly and finely punctate, with yellowish pubescence; shining, fuscous, but with the broad epipleurae and 4th and 5th ventral segments testaceous. The sternal structure corresponds with that of the New Zealand *S. acceptus*, 1131.

Easily known by the large fulvescent elytral spots.

Length, $2\frac{1}{2}$ mm.; breadth. $1\frac{1}{2}$ mm.

Pitt Island.

Discovered by Mr. T. Hall. Evidently rare.

ART. XIII.—*Notes on Entomological Collecting Tours during the Seasons 1908–9 and 1909–10.*

By H. HAMILTON, A.O.S.M.

Communicated by A. Hamilton.

[*Read before the Wellington Philosophical Society, 6th July, 1910.*]

A. SEASON 1908–9.

THE following is an account of a collecting tour undertaken by myself and Mr. F. S. Oliver on behalf of the Dominion Museum during the season 1908–9.

Our instructions were to collect as many specimens of *Lepidoptera* as possible, for the purpose of making comparisons between series of species from different localities.

We started collecting on the 2nd November, 1908, and ended on the 30th March, 1909, practically five months in all.

On the 9th November, 1908, we journeyed from Dunedin to Moeraki, a small fishing seaport south of Oamaru. We were specially instructed to look for pupae and larvae of *Argyrophenga antipodum*, a peculiar variety being found in that locality. Although we failed to find any traces of *antipodum*, a large variety of moths was taken at treacle in the bush round the port.

We noted a large number of *Melanchra ewingi* flying about in the sun and feeding on the wallflower in Mr. Hart's garden.

The same evening we treacled again in the bush on the hillside, with satisfactory results. The catch included *Leucania moderata*, *Melanchra decorata*, *M. disjungens*, *M. ewingi*, *M. levis*, *M. mutans*, *M. omoplaca*, *M. prionistis*, *M. plena*, *M. stipata*, *M. vitiosa*, *Rhapsa scotosialis*, *Selidosema dejectaria*, *S. panagrata*, *Venusia undosata*, *Chloroclystis bilineolata*, *Tatosoma agrionata*, *Elvia glaucata*, *Hydriomena callichlora*, *Asaphodes siris*, and *A. megaspilata*.

Collecting in the daytime gave very poor results, only one *Vanessa cardui* being seen, but treacling in the evening was a greater success than ever. The night was warm, and the treacle was laid just after sundown. On one patch of treacle alone fifty *Melanchra ewingi* were counted, all struggling to get a share of the sugar.

In addition to the captures of the two previous nights, we got *Orthosia comma*, *Melanchra neurae*, and *Agrotis ypsilon*, besides two more *Melanchra levis*.

We left Moeraki next day, and proceeded to Waikouaiti and Waitati, but beyond a few common moths nothing worth recording was taken. No doubt the poor catches in this place were due to the attractiveness of the native flowers.

After spending a few days in the neighbourhood of Dunedin we proceeded to Outram, or, rather, Woodside, a small township at the foot of the Maungatua Range. There is some very fine native bush to be seen there, especially in a place called "The Glen." Contrary to our expectations, and perhaps owing to the inclemency of the weather, our collecting was very poor. Night work was poor, and our only results were obtained by beating the bushes vigorously *Melanchra ewingi* was plentiful, and used with excellent results by the local sportsmen as a bait for trout fishing.

On the 26th November we proceeded to Waipori, being instructed to make a special collection of *M. disjungens* from this locality. The country is mainly covered with tussock-grass. Our first evening's treacling was round the fence-posts, and although a biting cold wind was blowing we had fair results. Great was the excitement when it was noticed that there was a peculiar whitish moth unknown to us on the treacle, along with *Leucania moderata*, *Orthosia comma*, *Melanchra ewingi*, *M. mutans*, and *M. disjungens*. During our three days' stay there we got a remarkable series of this moth, which eventually proved to be *Physetica caerulea*. The forms range from an almost pure white with yellow spots to dark steel-blue, the typical form. Such a remarkable case of variation is seldom met with, especially in one locality. The day collecting was very poor at Waipori, as the weather was dull and cold, with cold fogs at night. A few *Argyrophenga antipodum* were taken, and several species of *Notoreas*.

Our next rendezvous was Lumsden, *en route* for the Cold Lakes District.

At Lumsden we treacled on the fence-posts in the river-bed of the Oreti, the only vegetation being gorse-bushes. Good results were obtained, comprising *Melanchra moderata*, *M. mutans*, *M. ewingi*, *M. disjungens*, *Orthosia comma*, *Leucania griseipennis*, and *Melanchra lithias*. The last named was forwarded as *mutans*, but on inspection was found to be the rarer moth.

The following day a few *Argyrophenga antipodum* were taken on the hills near Lumsden, and immense numbers of *Nyctemera annulata* were seen everywhere.

Queenstown was reached the same day, and two days later, on the 7th December, we reached Macetown, our principal field for operations.

The following morning we found the ground covered with snow to a depth of 2 in. Macetown is situated at an altitude of 2,000 ft., and is subject to peculiarly rapid changes of climate. We were bitterly disappointed to see the higher hills covered in snow, as we were going to make special efforts to get alpine forms. However, the snow soon started to melt, and we impatiently waited for finer weather. In the evenings we treacled in many places round the township, having the schoolhouse for the centre of our operations.

During our stay at Macetown, from the 7th to the 21st December, we obtained an incredible number of moths at the treacle alone. Even on rainy and cold windy nights there used to be hundreds of the commoner moths round the treacle. The following is the list of the moths that were extremely common: *Orthosia comma*, *Leucania atristriga*, *L. moderata*, *L. unica*, *Melanchra cucullina* (?), *M. disjungens*, *M. ewingi*, *M. mutans*, *M. plena*, *M. ustistriga*, *Bityla defigurata*, and *Agrotis ypsilon*. The less-common varieties included *Physetica caerulea*, *Leucania griseipennis*, *L. nullifera*, *L. semivittata*, *L. unica*, *Ichneutica ceraunias*, *Melanchra maya*, *M. paracausta*, *M. pictula*, and *M. rubescens*. During those fourteen days we probably forwarded over sixteen hundred moths and butterflies to Wellington.

On Saturday the 12th December we made our first excursion into the localities known to be the habitat of *Erebia pluto* var. *micans*. Strange to say, a locality at an altitude of about 3.000 ft. on the Arrow River which at about the same time of the year in 1907 yielded many specimes of *Erebia micans* failed to give us any specimens. We took only one battered *micans* and saw one other, but were rewarded for our long tramp by getting a fine series of about eighty *Metacrias huttoni* on a tussocky island on the Arrow River. We did not see any females, but judged them to be present by the way the *huttoni* continually hovered over bunches of tussock, apparently on the look-out for something. A few *Argyrophenga antipodum* and several species of *Notoreas* were also taken that day.

Another locality was visited next day, and the results were better, although the sun was continually being obscured by clouds. *Erebia pluto* can only be located when the sun is shining strongly and continuously. This beautiful black butterfly is then to be seen hovering over the shingle-slips, and apparently following well-defined air-tracks. It was noticed that the best way to capture them was to sit close by a place they had been seen to pass, and keep perfectly still. Presently one would come sailing along, and apparently not notice the collector. A very quick movement with the net was necessary to catch the insect, and if you missed the first stroke the chances were all on the butterfly escaping. On being disturbed they make rapid jerky upward movements, and soon get out of the danger-zone, flying away to some other slope. As soon as the sun is obscured by a cloud all the butterflies alight and remain motionless till the sun shines again. As sunshine is the exception rather than the rule on these mountain-tops, *Erebia*-hunting is very trying to the patience.

Notwithstanding the unfavourable weather, we managed to get about twenty-five *Erebia micans* in good condition during this, our first, visit to Macetown. *Ichneutica ceraunias* and *Leucania griseipennis* were fairly common, but in bad condition.

Hoping that the weather would clear up for good, we started back to Queenstown on the 22nd December, on the way to Glenorchy. Glenorchy was reached on the 29th December, and our hopes were for a spell of fine weather, in order to work the tempting mountains that lie on the west side of Lake Wakatipu. We were especially anxious to get specimens of that rare butterfly *Erebia* or *Erebiola butleri* from a locality on the Humboldt Mountains discovered by Mr. G. V. Hudson, F.E.S., in 1894. A fall of snow and cold and boisterous weather gave the mountains a mantle right down to the bush-line (3,600 ft.), and all we could do for ten days was to sit in the hotel at Glenorchy and wait. We waited and waited until we almost despaired of seeing fine weather again, and eventually left Glenorchy (in the rain) for the south in search of finer weather.

We went right down to Invercargill, finally stopping at Wallaceville, about nine miles out of town. Mr. Philpott, who lives near there, was exceedingly kind to us, and gave us the benefit of his wide experience of collecting in those parts. When out with him one evening we had the good fortune to take two specimens of that rare moth *Melanchra exquisita*, of which previously there were only four specimens known. We also got seventy-odd fine specimens of a dark variety of *Argyrophenga antipodum* from the rushes in a paddock.

Our next instructions from headquarters were to go back to Macetown, as we seemed to have been most successful there Stopping at Lumsden, we laid down the treacle on fence-posts round the town, and were rewarded by getting a number of moths in excellent condition. A dark variety of *Orthosia comma* was plentiful, and the following comprised the rest of the catch: *Leucania atristriga*, *L. moderata*, *L. propria*, *Melanchra disjungens*, *M. ewingi*, *M. mutans* *M. prionistis*, *M. plena*, *M. rubescens*, and *Bityla defigurata*.

The following day, in Queenstown, we took *Vanessa cardui*, *Chrysophanus enysii*, *C. salustius*, *C. boldenarum*, and *Lycaena phoebe* during a walk round the track to Glenorchy.

We arrived back at Macetown on the 22nd January, and for the first few days the weather was execrable from an entomologist's point of view, although the mining-men seemed to be perfectly satisfied.

During the first three days at Macetown we kept a tabulated record of the moths taken at night. The following is the list:—

	22nd.	23rd.	24th.
Orthosia comma	24	15	2
Leucania atristriga	78	71	71
,, *griseipennis*	1	1	1
,, *moderata*	4	12	4
,, *nullifera*	1	2	..
,, *propria*	52	48	40
,, *semivittata*	..	2	4
Melanchra disjungens	1	..	1
,, *ewingi*	..	3	2
,, *maya*	..	4	1
,, *mutans*	3	5	4
,, *pelistis*	12	18	13
,, *prionistis*	..	1	1
,, *rubescens*	.	6	12
,, *ustistriga*	..	..	1
Bityla defigurata	1	1	..
,, *sericea*	4	8	3
Agrotis ypsilon	6	30	11

It must be understood that there were countless numbers on the treacle, and the ones listed are only those in perfect condition, and which were posted to Wellington.

On the 27th January, as the weather showed signs of clearing, we packed up for a stay in a hut up Advance Peak. This shepherd's hut is situated on the site of an old mine called the Sunrise. Advance Peak itself is 5,650 ft. above the sea-level, and the hut is considerably over 5,000 ft. A good track leads right to the door, and we were fortunate in having our

goods packed up by horse. The only vegetation is the stunted heath and tussock (snow-grass).

On the following day, a beautifully fine one, we had a most enjoyable collecting. Among the species that we took were *Erebia pluto, Vanessa gonerilla, Argyrophenga antipodum, Leucania griseipennis, Dasyuris hectori, D. anceps, Notoreas insignis, N. orphnaea, N. mechanitis, N. peronata, N. trephosata, N. zopyra,* and *N. vulcanica.* We came to the conclusion that the time for *Erebia micans* was over, as this butterfly was known to be plentiful in that locality earlier in the season.

During a ten days' stay up the mountain a large number of species was captured, and especially notable was a *Melanchra pictula,* on the treacle, at 5,000 ft.

Treacling at Macetown proved remarkably successful. There were so many moths round each patch of sugar that we did not know how to pick out the rarities. The best were ten beautiful examples of *Melanchra pictula* and fourteen of *Melanchra maya.*

It is a curious fact that we failed to notice a single specimen of *Leucania unica* during our second visit to Macetown. They seemed to have disappeared entirely, which is remarkable, considering what an enormous number there were only a month before.

During our two visits to Macetown we estimated to have sent between five and six thousand specimens of various species to Wellington for selection.

Our next instructions were to proceed to Glenorchy, at the head of Lake Wakatipu, and make special endeavours to get specimens of *Erebia butleri.* Accordingly we left Macetown, and arrived at Glenorchy on the 10th February, 1909.

The following day being beautifully fine, a start was made for Bold Peak, on the Humboldt Range. Half an hour's easy rowing across the lake and a steep climb of about 2,500 ft. over burnt-forest area brings you to the sharply defined bush-line Almost as soon as we got into the snow-grass and tussock *Erebia butleri* was seen flying lazily about in the sunshine. Proceeding a few hundred feet higher, we were soon busy taking it. *Argyrophenga antipodum* were extremely abundant, but we confined ourselves chiefly to the capture of the rarer butterfly. On that day and another which we spent in that locality we succeeded in getting nearly a hundred specimens of *E. butleri,* the proportion of females (all in poor condition) being 1 in 10.

The alpine flora to be seen on that range is wonderful, and at a higher altitude we seemed to be in one of nature's most beautiful rock-gardens. It would need more than the description of even an ardent botanist to fully appreciate the beautiful sights to be seen there.

Higher up still, at an altitude of about 6,000 ft., we came upon small colonies of the true *Erebia pluto.* Twenty-three specimens, of unusually large size, and in the best possible condition, were taken from the shingle slopes on Bold Peak. It was again noticed that these *Erebias* had a habit of flying over well-defined air-tracks, and they were also extremely hard to kill, as they frequently revived after being in the cyanide killing-bottle for half an hour or more.

Our next journey was to the Routeburn Hut, at the foot of Lake Harris Saddle. We spent five days there, and encountered very mixed weather. One fine day spent on Lake Harris Saddle was very disappointing to us, and we took only two *Erebia butleri,* a few *Argyrophenga antipodum,* and several species of *Notoreas.* The flowering-plants seemed to be over, and there was

very little insect-life to be noted. We were disappointed at this, as we were looking forward to some interesting collecting on this saddle.

The bad weather-conditions (cold, sharp nights) made the night collecting poor round the hut. The ribbonwood (*Plagianthus Lyallii*) was in full bloom, and we got most of the moths round that, with lights. *Declana floccosa* and *Melanchra rubescens* were very common, with an occasional *M. mutans*. One very battered specimen of that beautiful and rare moth *Leucania purdei* was taken round the ribbonwood-blossom. Treacling failed to produce anything, the blossom being too strong a counter-attraction. We left Routeburn feeling that we had not been sufficiently rewarded for our efforts.

We left the Cold Lake District finally on the 20th February, and returned to Invercargill district, with the hopes of getting good collecting round the ragwort and Canadian thistle that infest the locality.

Wallacetown, Orepuki, Moeraki, and Rangitata were visited without much result.

Castle Hill, on the old West Coast Road, was next visited, in the hopes that we might be able to find forms recorded by Enys many years ago. *Erebia pluto* is said to occur on the ranges in the vicinity of Mount Torlesse; but, whether the weather was too bad or the butterflies were over for the season, we were unsuccessful.

Finally we were ordered to Nelson, with instructions to work the Dun Mountain thoroughly. The weather and the lateness of the season combined to make our trip unprofitable. Apart from a few of the special form of *Argyrophenga* from the Dun Mountain, one *Dodonidia helmsi* and a few *Noctuae* obtained round Nelson, we did not get anything worth recording. This is unfortunate, as Nelson is a good locality for collecting, as is evidenced by the good local collections of *Lepidoptera* that are to be seen.

We left Nelson on the 29th March, and concluded operations for the season 1908–9.

It is a well-established fact that this season was an unusually bad one, regarded from an entomologist's point of view. Not only in the South Island did we have the bad weather, continuous reports from collectors in the North told of equally bad weather in their districts, and we must be thankful that we did so well while the fine weather lasted. Without a doubt Macetown was the most productive numerically, but I doubt if the series of *Physetica caerulea* obtained from Waipori was not more interesting. The wonderful variation in the same species, and the gradation from one marking to another, makes this series especially valuable.

The practice of taking all moths in good condition from every locality tends to show that some forms are most variable, and in others it is impossible to detect any variation.

It is hoped that our modest endeavours to record entomological facts will be appreciated, and we are deeply thankful to the Dominion Museum Department for the opportunity of doing so. Our knowledge of the New Zealand *Lepidoptera* must necessarily be incomplete until a large amount of collecting and recording is done.

B. Season 1909–10.

The following notes and observations were made by the writer during the season 1909-10—from the 26th November, 1909, to the 25th March, 1910—he being employed by the Dominion Museum as collector during this period.

As in the previous season four months of collecting had been done in the South Island, it was intended that operations were to be confined chiefly to the North Island of New Zealand, but eventually a considerable time was spent in Southland and Westland. This was due to the fact that the North Island seems to be poorer in *Noctuae* than the South.

Active operations were commenced on the 29th November in the neighbourhood of Morere, Hawke's Bay, a small settlement with notable hot springs. The native bush in the vicinity of Morere has been nearly obliterated by the advent of the settler, but there is one splendid patch round the hot springs conserved by the Government for scenic purposes.

Sugaring and attracting by light were the chief methods employed to get collections of the moths. During my fortnight's stay here the weather was not good, and collecting suffered to a certain extent.

Amongst the commoner *Noctuae* taken at treacle were *Orthosia comma, Leucania atristriga Melanchra ewingi, M. insignis, M. lignana, M. mutans, M. pelistis, Bityla defigurata, Ipana leptomera, Declana floccosa*, and *D. junctilinea*. I also had the good fortune to take a perfect specimen of *Cosmodes elegans* at treacle, and also that rare moth *Orthosia margarita*. Two good specimens of *Hepialus virescens* were taken at light in the bush, and later on in the season they would do doubt be common, as nearly every makomako (*Aristotelia racemosa*) showed evidences of extensive borings by the caterpillar of that moth. In the same locality four years previously I caught a beautiful orange-yellow variety of the male *Hepialus* hanging on to one of the incandescent lamps (fed by natural gas) that light the bush-track to the hot springs.

Collecting along this track in the dense bush was fair, and the following is a list of the species taken: *Tatosoma* sp., *Chloroclystis bilineolata, Hydriomena similata, Xanthorhoe cineraria, Leptomeris rubraria, Selidosema aristarcha, S. dejectaria, S. panagrata, S. suavis, Sestra flexata, Gonophylla ophiopa*, and a few *Crambi* and micros. On hot sunny days *Chrysophanus salustius* was fairly common on the watercress-flower, and the darker form, *C. enysii*, was also taken from the same places. *Lycaena phoebe* was also to be found, chiefly on the roadside, and an occasional hibernated specimen of *Vanessa gonerilla* was noted.

On the 17th December I left Morere, and proceeded by steamer from Gisborne to Auckland, with instructions to collect in the vicinity of the Waitakarei Ranges, about twenty miles south-west of Auckland. The bush on the Waitakarei Range is fairly heavy, and is not much interfered with by agricultural and pastoral operations.

Altogether I spent three days in the bush, and collected the following species: *Orthosia comma, Heliothis armigera, Plusia transfixa, Rhapsa scotosialis, Hydriomena deltoidata, H. gobiata, Venusia verriculata, Selidosema aristarcha, S. dejectalia, S. panagrata, Chalastra pelurgata, Sestra flexaria. Gonophylla nelsonaria, G. ophiopa, Drepanodes muriferata*, and *Ipana leptomera*. The *Plusia transfixa* mentioned is rather rare, and previously has been recorded only from the Thames district;* it is probably an introduced species, now naturalized; and the finding of *Gonophylla ophiopa* is a considerable extension of its northward range.

My next move took me to Kamo, about four miles out of Whangarei. and there I spent the New Year. Collecting there was very poor, and the only things of any note taken were *Heliothis armigera* and *Orthosia*

* Trans. N.Z. Inst., vol. 41, p. 5.

immunis. Among the commoner varieties were *Plusia chalcites, Leucania moderata, L. unipuncta, Melanchra ewingi, Rhapsa scotosialis, Hydriomena deltoidata, H. gobiata, Euchoeca rubropunctaria, Venusia verriculata, Xanthorhoe stinaria, Selidosema dejectaria, S. panagrata. Sestra flexata*, and *Drepanodes muriferata.*

Four specimens of a small micro were taken while beating for beetles, which proved on examination by Mr. A. Philpott to be *Coriscium miniellum.*

On leaving Kamo on the 8th January, 1910, I proceeded north as far as Russell, Bay of Islands At Russell I saw a single specimen of *Vanessa itea* on the summit of the historical Flagstaff Hill. The only moths taken at night were *Ipana leptomera* and *Orthosia comma.* The manuka scrub seemed to be alive with large singing locusts, *Melampsatta cingulata*, and several fine specimens were taken.

Apart from these cicadas there seemed to be a marked dearth of insect-life at this time. The same fact has been noted by Mr. A. Hamilton, the Director of the Dominion Museum, during his recent tour north of Auckland. The gum lands and manuka-scrub plains seem to be very poor in insects.

The collecting in the North being poor, I was recalled to Wellington, with the idea of trying the South Island fields again. Mount Arthur tableland was to have been visited, but eventually it was decided that I should go to the Humboldt Range, near Queenstown district, Lake Wakatipu. Collectors who had been in Queenstown district at Christmas brought very bad reports about the scarcity of *Lepidoptera* at that time, and I went expecting to be disappointed

The previous season, collecting for the Dominion Museum in company with Mr. F. S. Oliver, of Christchurch, we had a very successful time on Bold Peak, prominent on the Humboldt Mountains, and directly above Kinloch. Then we took that rare butterfly *Erebia butleri* and some large *Erebia pluto* on the higher slopes of the mountain, but we were unable to do any night work at these higher altitudes. Bold Peak is easily accessible from Glenorchy or Kinloch, and good collecting can be obtained above the bush-line, 3,600 ft. The flora on the slopes of Bold Peak is specially rich in *Veronicas*, and knowing what an attractive blossom *Veronica* is for *Noctuae* I was anxious to get some night work at these plants.

On the 31st January, 1910, I arrived at Kinloch, and by the evening of the same day had a camp pitched just above the bush-line on the way to Bold Peak. I treacled the birch bush in many places, but failed to attract a single moth, for reasons that were apparent later on. During the two following beautifully fine days I made excursions up to the altitude of about 6,500 ft., and had splendid catches of *Erebia butleri* and *E. pluto*.

The *butleri* seemed to be in poor condition, and, although the proportion of females to males was greater than that of the previous season, about fifteen males were taken to every female. This may be due to two facts—(1) a female *Erebia butleri* on the wing is easily mistaken for a dark male *Argyrophenga antipodum*, especially if you cannot see the underside ; (2) as a rule, the habits of the *E. butleri* are sluggish, and it does not make long flights ; it frequents some particular tussock-clump and flutters about there. Their position is generally indicated by watching the movements of the males, and noticing where they hover for a longer time than usual. During the bright sunshine the male *butleri* is seldom ever at rest, and appears to fly backwards and forwards along well-defined routes within certain natural boundaries. This "trade-route" habit is specially characteristic of the movements of *E. pluto* also.

Erebia pluto occurs on the slopes of Bold Peak from 3,600 ft. to where the snow-grass and tussock thins out, at about 6,000 ft. At the latter height you come on to the shingle-slips and rocky slopes where *E. pluto* reigns. I was fortunate in the two fine days I had on the mountain to get over thirty specimens of that butterfly, nearly all of which were in the best possible condition. The *plutos* from this locality are much larger than any other recorded specimens, having on the average an expansion of 55 mm. There seems to be great variation in the number of white spots on the upper wing, and in one case spots were found on the lower wing.

On the night of the 2nd February I had a wonderful time collecting from clumps of *Veronica* growing at about 3,700 ft. on steep rugged slopes. Just at dusk the moths started to collect, and I had a busy time netting. I found it was much easier and better to let the moths settle on the *Veronica* flower and then bottle them. *Melanchra pelistis* was exceedingly common, and the same can be said of *Orthosia comma*. A large number of *Leucania griseipennis* were taken, all in splendid condition and of unusual size. No less than eight *Melanchra maya* were taken on that same night, and also three of a new species, not unlike *Melanchra disjungens*.*

The following also occurred: *Melanchra rubescens, M. prionistis, M. pelistis, M. levis, Selidosema dejectaria, S. monacha* (a very rare and little-known species, of which male and female were taken), *Epirranthis alectoraria, Xanthorhoe clarata, X. cataphracta, X. adonis, Hydriomena deltoidata, Notoreas* sp., and a new species of *Selidosema. Dasyuris hectori* was also taken on the higher slopes of Bold Peak.

It will be seen that the locality is a very rich one, and taking three new or little-known species in a single night is very encouraging. It may be mentioned here that the season was much earlier this year owing to the exceptionally mild winter in that locality during 1909. Plants that were flowering at the same date in 1909 were entirely over, and no doubt this had some effect on the insect-life. Two new species of *Coleoptera* were found at high altitudes, and will be described by Major Broun.

After this successful time on Bold Peak I went down to the lowlands in the vicinity of Invercargill, collecting chiefly at Wallacetown and Seaward Moss. On the 10th February, in company with Mr. A. Philpott, of Invercargill, I made a trip to Seaward Moss, about twelve miles south-east of Invercargill, in search of a small species of *Notoreas* called *synclinalis.* Although the day was exceedingly windy, we managed to get about thirty picked specimens of that beautiful moth. On a fine day we should have taken any quantity.

In the vicinity of Wallacetown the following were taken off the ragwort, then in full bloom: *Orthosia immunis, Leucania semivittata, L. toroneura, Melanchra mutans, Tatosoma topea* and sp., *Elvia glaucata, Hydriomena deltoidata, H. gobiata, H. rixata, Venusia undosata. Xanthorhoe clarata, Selidosema dejectaria,* and *S. panagrata.*

On the 14th January I proceeded, by instructions, to Waipori, situated twelve miles west of Lawrence, at an altitude of 2,000 ft. In the season of 1909–10, in company with Mr. Oliver, a wonderful series of *Physetica caerulea* was taken on the 26th November, 1909, at this locality, and I was anxious to get some more specimens. On treacling round the same locality, and under perfect conditions, not a single one was seen, however, and, instead of having dozens of moths on each patch of treacle, the total catch

* To be described as *M. oliveri.*

for the night consisted only of *Orthosia comma* and two *Melanchra ewingi* (?). The following night was not so successful, as I failed to get even a single specimen. This can only be put down to the lateness of the season, although there were plenty of *Argyrophenga antipodum*, *Notoreas brephos*, and *Vanessa gonerilla* flying in the daytime. *Chrysophanus boldenarum* was very scarce in places where there were any quantity the year before.

On the way back to Wellington I stopped at Moeraki, and in company with Mr. G. Howes, of Dunedin, spent the night of the 23rd February treacling in the bush at the back of Port Moeraki. On that and the following night I took the following species: *Orthosia comma*, *Leucania sulcana*, *Melanchra decorata* (four specimens), *M. mutans*, *M. plena* (very common), *M. stipata*, *Rhapsa scotosialis*. *Venusia undosata*, *Xanthorhoe roscaria*, *Epirranthis alectoraria*, *Selidosema dejectaria*, *S. melinata*, *S. panagrata*, *Declana floccosa*, and *D. niveata*.

No more collecting was done until the 12th March, when I camped on Mount Greenland, near Ross, Westland. Mount Greenland rises to a height of 2,968 ft. above sea-level, and the top is fairly open country. I stopped at a hut in the subalpine vegetation, elevated about 2,500 ft., intending to see what moths came to a flowering bush of *Veronica* which grew at the door of the hut. I stayed there four nights, and got good results, especially on the warm misty nights when there was little cold wind blowing from the main range. Strange to relate, the commonest moth there was *Leucania alopa*, which is considered rather a rarity at other places. Every evening I treacled the stunted trees, and even treacled *Veronica* blossoms, but got nothing by that method; everything had to be netted. It is a peculiar fact that the smoke or heat from the hut-chimney seemed to attract many moths: perhaps they were only trying to get to the source of light. By far the most important capture was that of a single specimen of *Junonia velleda*, a butterfly that in 1886 was common in Wellington, and has been recorded from New Plymouth in 1893 and Motueka in 1898. Since 1898 no other specimens have been seen in the South Island until I got this damaged specimen at Mount Greenland on the 14th March, sheltering under a flax-bush during the pouring rain. Not expecting to find a rarity like that in such a locality, I mistook it for *Vanessa cardui*, and only by chance sent it up for examination.

The season was undoubtedly nearly over for collecting on the West Coast, but I made a trip to the Styx Saddle, near Browning's Pass, on the main Southern Alps. I did not expect to get much, but wanted to see if the locality was a suitable one for collecting earlier in the season. Nevertheless I took a large male *Porina*,* darker and less spotted than usual. Specimens of *Leucania alopa*, *L. atristriga*, and *Bityla defigurata* were also taken, but nothing else of any importance. Several golden-ringed black hairy caterpillars were taken feeding on a wayside plant, *Erechtites glabrescens*. These are considered to be a species of *Metacrias*, but so far have not been reared to maturity. The Styx Saddle contains about 30 acres of fine subalpine meadow land, and about New Year time should prove an excellent field for collectors.

On my way back to Wellington I walked over Arthur's Pass, in company with Dr. Cockayne, of Christchurch. The day was a fine one, but the only butterfly seen was one specimen of *Vanessa gonerilla*. After this, collecting was abandoned for the season, and I returned to Wellington on the 30th March.

* *Porina dinodes.*

ART. XIV.—*New Species of* Syrphidae.

By DAVID MILLER.

[*Read before the Otago Institute, 1st November, 1910.*]

THE two following species form a portion of a series of new species the remainder of which will be published in the near future.

Fam. SYRPHIDAE.

Genus HELOPHILUS Meigen (1822).

Hutton, Trans. N.Z. Inst., vol. 33, p. 36.

SPECIES.

Legs black; the hairs of frons divided from those of the vertex by a bare transverse band	*H. purehuensis.*
Legs yellow; hairs of frons not divided from those of vertex by a bare transverse band	*H. cingulli.*

H. purehuensis sp. nov.

Vertex black; frons yellowish-white, with dark hairs and a little dark tomentum; the hairs of frons divided from those of the vertex by a bare transverse band; the hairs of frons curved forward, becoming shorter toward the frontal lunule, which is bare, dark brown, and shiny, while those of the vertex are arranged with the longer posterior hairs anteriorly curved and the shorter anterior ones posteriorly directed; the row of hairs posterior to the vertical triangle are yellow. Eyes bare, dichoptic; ocelli vermilion. Face light yellow, bare, projecting outwards and downwards, but not so much in the latter direction as in the former; the central ridge of the face is shiny and of a deeper yellow, which colour, extending for about three-quarters the distance from the epistome to the base of the antenna, tapers suddenly to a point and disappears; epistome bare, shiny, dark brown, almost black; this colour extends to the margin of the eye; genae or cheeks, same colour as the face, bear delicate yellow hairs: delicate yellow hairs beneath the lower margin of the eye (jowls), becoming very short on the occiput. Proboscis of moderate length, posteriorly directed, black, except at the tip, where it is inclined to be reddish-brown. Antennae black; 1st and 2nd joints bristly, the latter joint bearing longer bristles on the anterior margin; 3rd joint ovoid, arista bare.

Thorax: Dorsum with 2 median and 2 lateral broad dark-brown longitudinal stripes; the intervening stripes are greyish-brown anteriorly, but from the transverse suture to the scutellar suture these stripes merge into black; the surface of the dorsum is covered with yellow hairs of medium length. Scutellum shiny, bronzy, clothed with long similarly pigmented hairs. Pleurae greyish, hairy; meso- and anterior ptero-pleurae bearing long golden hairs; halteres yellowish-brown. Wings tinged with brown, subcostal cell with brown spot about the junction of the auxiliary with the costa; veins brown, lighter in colour toward the base. Yellow hairs covering the surface of the legs, which are shiny black, except for the anterior and middle knees and the proximal half of the tibiae, which are dark yellow, and for the proximal portion of the swollen posterior femora, which is dark bronzy; posterior tibiae slightly curved; close-set short hairs

on inner surface of tarsi: ungues yellow, except for the shiny black tips: pulvilli yellow.

Abdomen shiny, covered on the dorsal surface with orange pile, and on the ventral surface with long yellow hairs: 1st segment—*i.e.*, the segment partially overlapped by the scutellum—bronzy; 2nd segment bronzy-black, except for 2 triangular orange spots, one on each side, the bases forming the lateral margins of the segment; the apices of these spots do not meet at the centre, but are separated by the stalk of a black T-shaped median patch, the cross of which forms the anterior margin of this segment. 3rd segment bronzy, except for a dome-shaped black spot having its base on the anterior margin and apex at the centre of the segment; the 4th segment as the 3rd, but inclined to be of a darker colour. The posterior margin of each segment is coloured by a black transverse band, broader at the centre than at the lateral extremities.

Length, 12 mm.; of wing, 9 mm.

Hab.—Captured above a stream, during very warm weather, near Purehurehu, January, 1909. Not common.

H. cargilli sp. nov.

Vertex and vertical triangle dark brown, the former covered with long black hairs; frons tawny brown with yellow reflections, and bearing hairs similar to the vertex; no dividing band between the hairs of vertex and frons; the hairs covering these latter portions arranged as in preceding species; frontal lunule bare, shiny brown; a slight median longitudinal groove running from apex of ocellar triangle to frontal lunule, reappearing at the base of the antennae, where it is prolonged down the face to the epistome. Eyes bare, dichoptic; ocelli vermilion. Face as in preceding; genae yellow, with long yellow hairs; epistome bare, shiny, dark brown, with a little yellowish-white tomentum at the connection with the jowls, which are themselves yellowish-white, and clothed with long silvery hairs, becoming shorter on the occiput. Proboscis and antennae as in preceding, except that the arista of the latter is slightly margined at the base by reddish-brown.

Thorax: Dorsum grey, covered with short dark hairs; has 2 median and 2 lateral longitudinal broad dark-brown stripes; the two former are divided by a narrow grey stripe, which tapers gradually anteriorly and suddenly posteriorly so that these two stripes are united at the scutellar suture; the two latter stripes slightly converge anteriorly, but do not reach the anterior margin of the thorax. On the dorsum, around the scutellar suture, is a patch of brownish-yellow reflections, which in certain lights connects the posterior extremities of the dorsal stripes. Scutellum orange, shiny, bearing long orange hairs. Pleurae yellowish-grey, with golden hairs surrounding the dorso-pleural suture. Halteres yellow, squamae translucent orange-fringed with long orange hairs. Wings clear, transparent; base of costal cell tinged with brown, subcostal darker brown for about three-quarters of the length, where the pigment ends abruptly; bases of the auxiliary 1st and 5th longitudinal veins shiny brown. Legs hairy, yellow, except the grey coxae, the trochanters, the proximal end of the femora, the first 4 tarsal joints, especially the posterior ones, and the posterior knees, which are black; the 5th tarsal joint of each leg is inclined to yellow; posterior femora swollen; short weak black spines on the distal extremities of the tibiae, the slightly curved posterior ones being excepted; rows of short black bristles on the middle and posterior tarsi.

Abdomen covered by golden pile, longer laterally; 1st segment orange laterally, greyish centrally—beneath the scutellum—with a black spot on each side of this grey portion; 2nd segment orange except for a T-shaped black patch—placed as described in preceding species—and for a dark-orange band running along the posterior margin, and also for 2 spots of greyish reflections, one on each side of the stem of T-shaped patch; 3rd segment much the same as preceding, excepting darker and larger reflections on the orange, leaving only 2 bright-orange veins; 4th segment dark orange, with a black central anterior patch and lateral greyish spots of tomentum; 5th segment grey, the black having almost disappeared.

Length, 13 mm.; of wing, 10 mm.

Hab.—Captured upon manuka-bush on Mount Cargill during very warm weather, February, 1909. Not uncommon.

ART. XV.—*New Species of* Lepidoptera.

By G. HOWES, F.E.S.

PART I.

[Read before the Otago Institute, 2nd August, 1910.]

Selidosema ochrea sp. nov.

Three males, 29 lines. Head ochreous-grey. Thorax fuscous. Abdomen ochreous, darker dorsally. Forewings: A small dark-fuscous mark from base below centre of wing; an irregular light-ochreous patch from base to $\frac{1}{4}$; an almost uniformly fuscous transverse band from $\frac{1}{4}$ to $\frac{3}{4}$, bending towards termen between veins 5 and 3; then a transverse ochreous area, followed by a band of uniform fuscous from $\frac{3}{4}$ to termen. Cilia fuscous, a faint ochreous line at base. Hindwings: Brighter ochreous than forewings, with a few faint irregular marks, mostly near termen. Cilia greyish-ochre.

The brightness of the ochreous markings easily distinguishes this from the allied *Selidosemae*. Nearest *melinata*, but is smaller and more distinctly marked. Two females taken at the same time may be of this species, but are so different in appearance that I am waiting further captures before deciding.

Taken at "treacle," Woodhaugh Gardens, Dunedin; February and April.

Eucymatoge arenosus sp. nov.

Male and female, 26 lines. Head and thorax whitish-ochre, slightly touched with grey. Abdomen whitish-ochre with black bar interrupted in centre on apex of all segments. All wings whitish-ochreous, crossed by waved darker striae. A slight darker suffusion from apex towards centre of forewing. Cilia greyish-white, with a darker-grey line at base. A series of minute black marks along veins and around termen.

All the specimens that I have examined show a surprising uniformity, and no difference is noticeable between the male and female in size and colour. Smaller and more compact than *Hydriomena gobiata*, it superficially has a strong resemblance to *Venusia verriculata*.

Taken at Mr. O'Connor's residence, at Titahi Bay, Porirua, Wellington, where it came in fair numbers to "treacle," light, and blossom; November to March.

PART II.

[*Read before the Otago Institute, 1st November, 1910.*]

Morrisonia praesignis sp. nov.

One male specimen expanding 37 lines, and one female 40 lines. Antennae filiform, reddish-brown. Palpi and legs reddish-brown. Tarsi with lighter bands at joints. Palpi pale reddish at tips, and rising from a reddish tuft. Face at base of antennae green. Thorax reddish-brown. Patagiae green edged with reddish-brown. Thoracic crests strong, green edged with brown. Abdomen ochreous red, darker towards extremity. Crests strong. Forewing rich red-brown, with well-defined green areas. A double subbasal line from costa to median fold. A greenish suffusion from base along close to costa as far as reniform. A well-defined light-green line at $\frac{1}{4}$ from costa to dorsum, bending outwards at centre; a light-green line at $\frac{1}{2}$, edging reniform, and bending outwards at centre; the space between these two lines reddish-brown. A well-defined subterminal line edged on basal side with deep reddish-brown and on terminal with green. Indentations slight. A greenish suffusion from base to posterior angle. Veins faintly outlined with dark-brown and green dots. Reniform dark below, white above. Cilia long, dark reddish-brown. Hindwings reddish-brown, with narrow dark reddish-brown suffusion along termen. Cilia lighter reddish-brown, with a darker line near base.

Two specimens came to "treacle" at Orepuki, September and October, 1910. Although close to *plena*, it is easily distinguishable.

Morrisonia longstaffii sp. nov.

Four specimens. Expanse, 28 to 30 lines. Antennae ferruginous-grey, filiform. Legs, palpi, head, and thorax grey irrorated with ferruginous. A dark mark across front of thoracic crest. Crests strong. Abdomen greyish-ochreous, lighter in colour towards anal tuft, which is light ochreous-grey. Forewings grey, markings ferruginous. Reniform and orbicular grey outlined with ferruginous. Base of wing light grey, followed by a dark jagged transverse line. A double jagged transverse line at $\frac{1}{4}$ across wing. A suffused patch around reniform, continuing as a well-defined jagged line with a faint line on each side to dorsum. A rather indistinct suffused line near termen. Cilia grey. Hindwings uniform dark-grey. Cilia silvery-grey with a dark-grey line at base.

I took a single specimen in Dunedin on the 28th March, 1907, and a good series when collecting with Dr. Longstaff at Queenstown and Paradise, Lake Wakatipu district, in second week of March, 1910.

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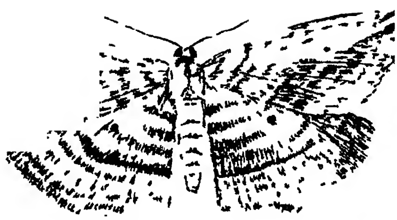

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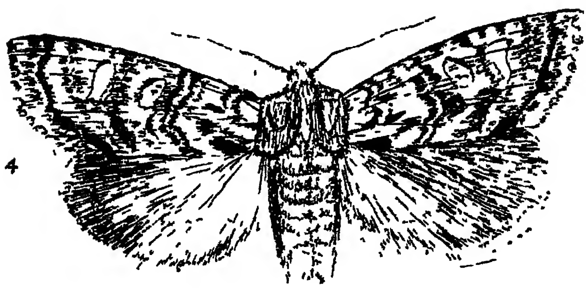

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G. H del

1 Selidosema ochrea.

2 Eucymatoge arenosus.

3. Morrisonia longstaffii

4 Morrisonia praesignis

Face p. 128]

ART. XVI.—*Notes on the Larvae of some New Zealand* Lepidoptera.

By R. M. SUNLEY.

[*Read before the Wellington Philosophical Society, 6th July, 1910.*]

Melanchra rhodopleura Meyr., Trans. N.Z. Inst. vol. 19 p. 19.

Ten specimens of the very pretty larva of this insect were taken at Makara at the beginning of October, 1909.

The length was then about $\frac{3}{4}$ in. The colour was a very pretty pale green. A well-marked median dorsal stripe, white alternated with sulphur-yellow, the white portions being situated near the junctions of segments, and being tinged at the junctions with lilac. Faintly marked subdorsal stripe, yellowish-green. Lateral stripe broad, well marked, made up of 4 longitudinal lines of colour, the lowest one sulphur-yellow, followed by one of orange-yellow, then a broader one of white, then a very narrow edging of black, on which are situated the spiracles, which are cream-colour edged with black. Each segment has a number of small black warts—2 on each side of the dorsal line, 1 between the subdorsal and lateral line immediately above the spiracles, and a number on the ventral surface and prolegs. These warts, especially those on the dorsal surface, are edged with paler green than the body-colour, and are each furnished with a short brown bristle. On segment 2 the warts are bigger, and there are 3 between the dorsal and subdorsal line. After the last moult the green colour is much darker. The dorsal stripe is edged with black, especially on posterior end of each segment. The subdorsal lines are plainer and yellow in colour, upwardly edged with black, and the posterior half of each segment becomes spotted with black between the subdorsal and dorsal lines. The length when full grown is $1\frac{1}{2}$ in.

The food plant is *Pimelea laevigata*, and the larva feeds on the leaves, young shoots, and flowers. When disturbed it often rolls itself up and falls to the ground.

The pupa is at first light brown in colour, becoming darker as the insect develops. It is enclosed in a cocoon below the surface of the ground. The period of pupation is variable; the perfect insects appeared from end of December to end of April, though the larvae were all full grown about the middle of November. The perfect insect is very sluggish in habit, and this, together with its very protective colouring, may account for the fact that it is so seldom captured.

Leucania epiastra Meyr.

The eggs of this species were laid on the 14th November, 1908, by a female in captivity. They were firmly fastened close together on the side of the box in which she was kept. In shape they are spherical, flattened at the base, and rather coarsely ribbed, the ribs radiating from a dot at the top. The colour is at first uniform pale yellow, but after a few days the central dot becomes dark brown and a dark-brown circle appears round it.

The larvae emerged on the 30th November. The length is about $\frac{1}{8}$ in., and the larva is very active. It makes its first meal off its egg-shell. The colour is greenish-brown, becoming paler after a few days. On each segment are a number of black dots, from which spring hairs. The larva has

16 legs, but those on segments 7 and 8 do not seem to be fully developed at this stage.

On the 20th December the larvae were about ⅜ in. in length, pale greenish-brown in colour, with dark reddish-brown lateral line. At this stage they unfortunately died. They were feeding very sparingly on the leaves of what I thought at the time was toetoe, but which I afterwards found was pampas-grass.

In May, 1910, I took a number of these larvae on the toetoe at Makara: they were from 1 in. to 1½ in. in length. The larva feeds on the leaves by night, retreating during the day to the crevices at the base of the leaves, where they are well protected from enemies.

The full-grown larva is dull brownish-green in colour, sometimes tinged with reddish-brown, especially on posterior segments. The dorsal and sub-dorsal lines are very narrow, but fairly well marked; dull white in colour, faintly edged with red or reddish brown. The lateral line is somewhat indistinct, white in colour. On it are situated the spiracles, which are dull cream-colour edged with black. The lateral line is often edged with small brown blotches situated above the spiracles, and on the anterior segments these blotches are sometimes joined to form a broad, faintly marked upward edging to the lateral line. The integument, especially on the dorsal surface, has a number of fine white branching veins, and on each segment are a number of minute black dots from which spring short brown bristles. The prolegs are of the same colour as the body, edged with a large number of dark-brown hooks. The head is horny, amber in colour, mottled and netted with brown. The number of legs is 16. Length when full grown, 1⅞ in.

The larva now makes its way into the flower-stem preparatory to pupating. It enters the stem, and eats its way through the soft interior, forming a chamber 2 in. or 3 in. long between two joints. It now loses its green colour, and changes to a pale dull brownish-yellow, the dorsal surface often strongly tinged with pink. This pink tinge becomes very marked as the time of pupation approaches. The larva spends some weeks in the stem, and before changing to a pupa cuts a neat round hole through the stem, near the top of its chamber, leaving only a very thin film of the outermost layer intact. It then retires to the bottom of the chamber, and in a few days changes to a pupa, which rests on the old larval skin, head upwards.

The pupa is very robust, and is at first light brown in colour, but soon becomes very dark brown and shiny.

After about six weeks the imago emerges, and, breaking its way through the thin film of leaf covering the exit from its chamber, crawls out and clings to the stem till its wings have expanded and hardened sufficiently for it to fly. The emergence usually takes place between 7 and 9 o'clock in the evening.

The perfect insect is about from October to January. It is very sluggish, and I have never seen one in a state of nature, though I have spent a good deal of time in a locality where the larva is fairly common.

The larva of this insect is sometimes attacked by a dipterous parasite.

ART. XVII.—*Note on the Dispersal of Marine* Crustacea *by Means of Ships.*

By CHARLES CHILTON, M.A., M.B., D.Sc., F.L.S., Professor of Biology, Canterbury College, University of New Zealand.

[*Read before the Philosophical Institute of Canterbury, 7th December, 1910.*]

IT has several times been suggested that some of the marine *Crustacea* may be unconsciously dispersed by man, owing to their becoming attached or temporarily adhering to the hulls of ships. So far as I am aware, however, few definite facts of this means of dispersal have been recorded.

Mr. Stebbing (1888, p. 1135), in recording a specimen of *Podocerus falcatus* (Montagu) from Kerguelen Island, remarked, "There is the possibility, as I have elsewhere suggested, that these creatures may have travelled out from our own waters along with the vessel to the southern latitude at which they were captured." This species, however, which Stebbing gives in his "Das Tierreich Amphipoda" (1906, p. 654) under the name "*Jassa pulchella* Leach," proves to be very widely distributed both in northern and in southern seas, and may have been dispersed, as I have pointed out (1909, p. 647), owing to its habit of attaching itself temporarily to the carapace of *Jasus edwardsii* and other large *Crustacea*; and, though it is possible it may also be distributed by attaching itself to ships in the same way, this explanation seems hardly necessary for the particular case Mr. Stebbing was then considering.

In his "History of Crustacea" Mr. Stebbing gives a more certain example of this means of dispersal. He says (1893, p. 98), "In the winter of 1873 an iron vessel entered the port of Marseilles. It had come from Pondichéry by way of the Cape of Good Hope having had a long and stormy voyage in the most rigorous season of the year. To the iron plates of this ship had become attached a little forest of algae and barnacles, and living among these were a number of higher *Crustacea* of exotic origin. Two of the specimens were found by Professor Catta to belong to a new species, which in 1876 he named *Pachygrapsus advena*; one was a *Nautilograpsus* (or *Planes*) *minutus*, a species scarcely ever found in the Mediterranean; the remainder belong to two species, which M. Catta speaks of as *Plagusia squamosa* and *Plagusia tomentosa*." Mr. Stebbing points out that the latter species should be called *Plagusia chabrus* (Linn.), and the former *Plagusia depressa* (Fabricius). The last-mentioned species was the most abundant, being present in hundreds, though, as Mr. Stebbing points out, being an Atlantic species it might not have had to come far. There seems no doubt that the species mentioned had been brought from other places into the Mediterranean by their becoming attached to the hull of this ship. Dr. Alcock (1900, p. 437) has since pointed out that the *Plagusiae* resemble *Varuna* in being able to make themselves at home on drift timber in the open sea, and that the wide range of some of the species can be thus accounted for. He states, however, that the two species found in the Mediterranean may very probably have been carried there by ships, and adds that on the "Investigator" *Plagusiae* could always be seen adhering to the ship's sides near the water-line.

We have another example of this method of dispersal in the case of the common European shore-crab *Carcinus maenas*. Dr. Alcock says (1899,

p. 14) that this crab is found at various places on the Atlantic coast of the northern United States and off the coast of Pernambuco (Brazil); that in Europe it extends in the North Sea almost up to Arctic limits, and is common in all parts of the Mediterranean, being also found in the Black Sea and the Red Sea; and that it is also an Indian species, though evidently very rare. He adds that it "has been reported from the Hawaiian Islands from the Bay of Panama, and—though there is doubt about this locality—from Australia." He proceeds to point out that the distribution is not altogether without parallel among other marine forms, and is therefore not so singular as has been supposed. In 1901 Messrs. Fulton and Grant (1901 p. 56) pointed out that this crab does undoubtedly occur in Australia in the waters of Port Phillip, where it is now exceedingly abundant, and they state that there seems little doubt that it has been introduced there by the shipping. In their paper they quote Consul Gunnerson as suggesting that it may have found its way from Europe to Australia through the medium of the old lumber-ships attracted thither in the early "fifties" on the discovery of the goldfields, many of these vessels having been far from seaworthy and been patched up with false bottoms which had become riddled with *Teredo navalis* and fouled with marine growths, affording ample shelter for the fry and young crabs on their long voyage. Messrs. Fulton and Grant suggest that this explanation may also account for the scattered distribution of the species as indicated by Dr. Alcock.

I am now able to add another example of the same method of dispersal. When the British Antarctic ship "Terra Nova" arrived in Lyttelton in October, 1910, it was stated in the newspapers that the sides of her hull were covered with a plentiful growth of seaweed, barnacles, &c., and that after she was tied up to the wharf numerous fish were seen feeding on these. As soon as possible after she had been taken into dock I visited the vessel, but, unfortunately, before I could get down the water had been pumped out of dock, and her sides had been already scraped. From the floor of the dock, however, I secured the following cirripedes: *Lepas hilli* Leach, *Lepas australis* Darwin, *Conchoderma aurita* Linn., *Conchoderma virgata* Spengler, and *Balanus tintinnabulum* Linn. These are all species which are known to attach themselves to floating logs, and they are also commonly found on ships, and they therefore present nothing new of interest. However, in one of the planks which had been partially split, and therefore removed by the workmen, there were found four specimens of a large sphaeromid *Cymodoce tuberculata* Haswell,* both male and female specimens, two of these being still alive when I secured them.

This species is quite unknown in New Zealand waters, but is an Australian one, and there seems little doubt that it had attached itself to the ship while she was staying in Port Phillip, and had travelled with the ship all the way to New Zealand—*i.e.*, about twelve hundred miles. The hull of the ship is not covered over with copper, but is all wood. The

* My specimens do not quite agree with Haswell's description and figures in the amount of tuberculation of the body and in the details of the processes on the pleon, and they may prove to be a distinct but allied species. The two specimens which I consider to be the females of the species differ greatly in general appearance from the males, as is generally the case in this genus, and I have not yet been able to identify them with any form already described. These questions must be discussed elsewhere, and they do not affect the present argument, which depends on the fact that the species in question is certainly not known from New Zealand, and is either identical with an Australian species already described or very closely allied thereto.

"Terra Nova" had sailed from England down the Atlantic, calling at South Trinidad, off the coast of South America; then at Cape Colony, where she stayed some short time; and then to Hobart and on to Melbourne. From Melbourne she came direct to New Zealand, coming round the south through Foveaux Strait. It is worth while drawing attention to the fact that in this case both male and female specimens were carried together, so that the establishment of the species in any favourable locality to which they might be taken would be quite possible.

Naturally the *Crustacea* that are suitable for dispersal by means of ships can also be dispersed by floating logs; in that case, however, they would follow the tracks of the prevailing currents, while the dispersal caused by ships would be erratic, and could not be understood without some knowledge of the prevailing routes taken by the ships.

ADDENDUM.

Since this paper was read before the Philosophical Institute of Canterbury Mr. T. F. Cheeseman, of the Auckland Museum, has kindly communicated to me the following occurrence, which appears to be an example of a somewhat similar nature.

About two years ago, happening to hear of a curious crustacean in a fishmonger's shop in Auckland, he went to see it, and was surprised to find a freshly caught specimen of *Limulus*. He was able to secure the specimen for the Museum, and, as the result of inquiries, found that two fishermen had observed the *Limulus* adhering to the stone facing of the Calliope Dock and had pulled it up with a boat-hook. No vessel had been in the dock however, for some considerable time.

It is uncertain, therefore, whether this specimen found its way to Auckland by adhering to the hull of a vessel or in some other way; but the occurrence of a live *Limulus* in New Zealand is certainly noteworthy. Mr. Cheeseman has kindly compared his specimen with the characters given by Pocock in his recent revision of the group, and identified it as *Carcinoscorpius rotundicauda* (Latr.), a species known from the Gulf of Siam, the Moluccas, and the Philippines.*

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* A single specimen of *Limulus polyphemus* was found in the harbour of Copenhagen in the eighteenth century, having presumably been carried over from North America by a ship to which it clung. (Ray Lankester, Q.J.M.S., vol. 48, p. 229, 1905.)

Art. XVIII.—*Revision of the New Zealand* Stomatopoda.

By Charles Chilton, M.A., M.B., D.Sc., F.L.S., Professor of Biology, Canterbury College, University of New Zealand.

[*Read before the Philosophical Institute of Canterbury, 7th December, 1910.*]

In the year 1891 I published a paper on the New Zealand *Squillidae*, stating what was known of the group at that time. Only two species were then known with certainty to occur in New Zealand—viz., *Squilla armata* Milne-Edwards and *Lysiosquilla spinosa* (Wood-Mason): but two other species—*Squilla nepa* Latreille and *Protosquilla trispinosa* (White)—had been recorded from New Zealand, though they were not represented in any of the local collections.

A few years later an important paper was published by R. P. Bigelow on the *Stomatopoda* collected by the "Albatross" between 1885 and 1891, and this paper incidentally contains a considerable amount of additional information on the New Zealand forms. Further references to some of them have also been made by A. Milne-Edwards in the "Mission du Cap Horn" and by Stebbing in his report on the South African *Crustacea*. Owing to the habits of these *Crustacea* they are not very frequently met with. but during the years since the publication of my paper some additional specimens have been collected, and in working out some from the "Nora Niven" collection I have been led to revise the few species that are known to occur in New Zealand and to present the results in this paper. In it I record one species, *Lysiosquilla brazieri*, which had not been previously known from New Zealand seas. I have also a specimen which is undoubtedly the same as those referred to *Squilla nepa* by Heller, but now known under the name of *Squilla affinis* Berthold, so that this species, which was previously considered doubtful, does occur in New Zealand; further, I am able to give some additional information on *Squilla armata*.

As regards their distribution, it may be noted that the four species that are certainly known to occur in New Zealand are all widely distributed. none of them being confined to the New Zealand region. *Squilla armata* extends around the globe in southern seas, *S. affinis* reaches to Hong Kong and Japan, *Lysiosquilla spinosa* is found in the Indian Ocean, and *L. brazieri* occurs in Australia, and is probably identical with *L. latifrons* from Japan.

For their kindness in supplying me with specimens I have to thank Mr. A. Hamilton, of the Dominion Museum; Mr. F. W. Hesse, of the Wanganui Public Museum; Mr. Edgar R. Waite, of the Canterbury Museum; and Professor W. B. Benham, of the Otago Museum.

I have given only those references which appeared necessary for New Zealand students, and I have added brief diagnoses of the genera and species where this seemed desirable.

Protosquilla trispinosa (White).

Gondactylus trispinosus White, List Crust. Brit. Mus., p. 87, 1847; Miers, Cat. N.Z. Crust., p. 90, 1876. *Protosquilla trispinosa* Chilton, Trans. N.Z. Inst., vol. 23, p. 61.

This species has been recorded by Heller from Auckland. It is widely distributed in Australian and Indo-Pacific seas, but, so far as I am aware,

is not yet represented in any local collection. It is quite possible that it may occur in the northern part of New Zealand, and the recent rediscovery of some of the species assigned to New Zealand by Heller which were thought at one time to be errors makes it desirable to keep this species still on the list as a possible occasional visitant to New Zealand seas.

Genus SQUILLA Fabricius.

Diagnosis.—"*Stomatopoda* having the telson attached to the 6th abdominal segment by a movable joint; the hind-body depressed and wide: the dactylus of the raptorial claw with usually not more than 6 teeth; as a rule, more than 4 intermediate denticles on the telson, which is usually longer than wide; and the inner basal spine of the uropod the longer of the two." (Bigelow.)

Squilla armata Milne-Edwards.

Squilla armata Milne-Edwards, Hist. Nat. Crust., vol. 11, p. 521, 1837; Gay, Hist. de Chile, Zool., vol. 3, Crust., p. 223, 1849; Miers, Ann. Mag. Nat. Hist., ser. 5, vol. 5, p. 25, 1880; A. Milne-Edwards, Mission du Cap Horn, p. F 53, 1891; Chilton, Trans. N.Z. Inst., vol. 23, p. 60, 1891; Whitelegge, Memoir Aust. Mus., vol. 4, pt. 2, p. 199, 1900; Stebbing, South African Crustacea, pt. 2, p. 45, 1902; Bigelow, Proc. U.S. Nat. Mus., vol. 17, p. 515, figs. 9 and 10, 1895. *Chloridella armata*, M. J. Rathbun, Proc. U.S. Nat. Mus., vol. 38, p. 609, 1910.

Specific Diagnosis.—"Eyes large, triangular, dactylus of the raptorial limb with 7 to 9 teeth; rostrum narrowed in front with a slight median elevation; carapace with median carina obsolete or entirely absent, intermediate and lateral carinae present only on the posterior lateral lobes, anterior lateral angles produced into acute spines; lateral spines of the 5th thoracic segment narrow, straight, and acute, the lateral processes of the next two segments broadly rounded and produced into spines that point backward; 8 carinae on the abdominal segments; telson with a crest and a keel and a series of curved lines of pits on each side, 6 marginal spines, the submedian pair with movable tips, no submedian denticles, 10 to 11 small intermediate ones, and 1 lateral one." (Bigelow.)

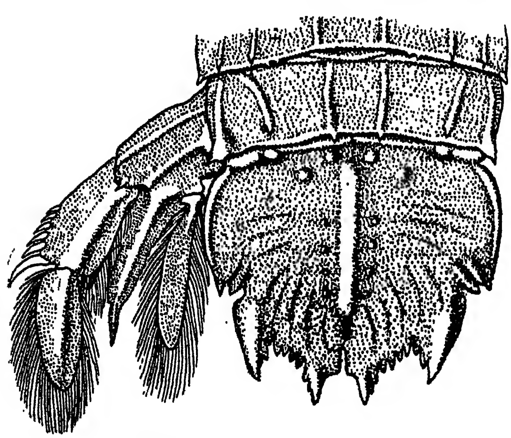
FIG. 1.—*Squilla armata*: Telson and uropod.

Length of largest specimen examined, 135 mm.; usual length, 60–80 mm.

This species is probably common in New Zealand seas, though it is only occasionally met with, most of the specimens in local museums having

been obtained from the stomachs of fish. I have seen specimens that were dredged in Wellington Harbour (T. W. Kirk); two fine specimens from Petone Beach, now in the collection of the Dominion Museum; others obtained during the "Nora Niven" expedition, in the stomach of a *Dasybatus* (Waite); two specimens from Kaikoura, in the stomach of an *Alepisaurus ferox* (A. D. Goodall). It has also been recorded from the Auckland Islands by Miers.

Distribution.—Widely distributed in southern seas, having been recorded from South America, South Africa, and Australia.

Remarks.—The specimens examined agree closely with the brief diagnosis given by Bigelow as quoted above. The median elevation on the rostrum is hardly appreciable, and the carinae on the carapace are only very slightly marked, especially in the smaller specimens. The submedian spines on the telson have movable tips, as described by Bigelow, in the smaller specimens, but in larger specimens the tips have become obsolete or been worn off. The curved lines on the sides of the median carina of the telson are fairly distinguishable, though the surface itself is quite smooth.

My specimens agree also with the more detailed description given by Bigelow, except that in smaller specimens the intermediate and lateral carinae do not end in spines in the four or five anterior abdominal segments; "the 1 to 4 small spines halfway between the median and intermediate carinae" on the posterior margin of the 5th segment of the abdomen appear to be constantly present.

In the characters of the telson and in some other points this species appears to approach pretty closely to *Squilla lata* Brooks from the Arafura Sea (see fig. 1).

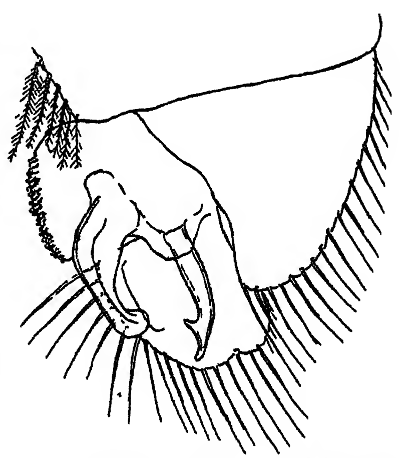

Fig. 2.—*Squilla armata*. Endopod of first pleopod of male.

Milne-Edwards, in the "Mission du Cap Horn," considers *S. gracilipes* as probably a variety of *S. armata*, and certainly, as he points out, the number of spines on the dactyls of the raptorial limbs is subject to variation, so that the possession of 10 in *S. gracilipes* is not sufficient in itself to distinguish it from *S. armata*; but Miers describes *S. gracilipes* as having 26 denticles (*i.e.*, 13 on each side) between the submedian marginal spines, and about 18 on each side between the submedian and the first lateral spines. In none of the adult specimens of *S. armata* that I have been able to examine are there any denticles between the median fissure and the submedian spine except in one instance where there are one or two small traces of a denticle, and Bigelow has drawn attention to the same fact, so that in this point there is a pretty considerable difference between *S. gracilipes* and *S. armata*; and there are other points drawn attention to by Miers which make it difficult to consider these two forms as specifically identical.

I have one small specimen, collected at Sumner, that is only 20 mm. in length; but since it has the submedian and lateral carinae faintly marked on the posterior abdominal segments, and ending in spines on the 6th

segment, it must, I think, belong to *S. armata.* In it the terminal segment shows little or no median fissure, and there are 12 small sharp teeth on each side between the median line and the submedian spine, and 16 between the submedian and lateral teeth, all these teeth being sharply pointed and occasionally irregular, with a small one in between two of the ordinary size. The raptorial limbs on each side bear 7 teeth on the dactyl.

In the character of the terminal segment and also of the uropods this small specimen appears to agree closely with Miers's description and figure of *S. gracilipes;* that species, however, is much larger—viz., 85 mm. long (" 3⅓ in.")—and presumably adult, and the dactyls of the raptorial limbs bear 10 teeth.

As Bigelow has pointed out, there are no secondary sexual differences in *S. armata.* The endopodite in the first abdominal appendage in the male is specially modified in the usual manner, and, as this appendage has not been described in this species, I represent it in fig. 2. It will be seen that it conforms closely to the type found in other species of *Squilla,* and a detailed description of it appears to be unnecessary.

Squilla affinis Berthold.

Squilla affinis Berthold, Abhandl. k. Gesellsch. Wiss. Gottingen, vol. 3 p. 26, 1815; Bigelow, Proc. U.S. Nat. Mus., vol. 17, p. 538, fig. 22, 1895 (with synonymy). *S. oratoria* De Haan, Siebold's Fauna Japon Crust., p. 223, 1850; Stebbing, South African Crustacea, pt. 4 p. 44, 1908. *S. nepa* Miers, Cat. N.Z. Crust., p. 89, 1876, and Ann Mag. Nat. Hist. (5), vol. 5, p. 25, 1880 (in part); Chilton, Trans. N.Z Inst., vol. 23, p. 60, 1891.

Bigelow has pointed out that under the name *Squilla nepa* two species have been confused. These species differ mainly in the eyes, one form having them small and with the corneal axis about three-fourths the length of the perpendicular one and at right angles to it, while in the other the eyes are large, triangular, with the corneal axis oblique and as long as or longer than the perpendicular one. The form with the smaller eyes he considers to be the true *S. nepa* Latreille, while the other form he assigns to *S. affinis* Berthold. Mr. Stebbing upholds *S. oratoria* De Haan as prior to *S. affinis* Berthold, and therefore the correct name for the species.

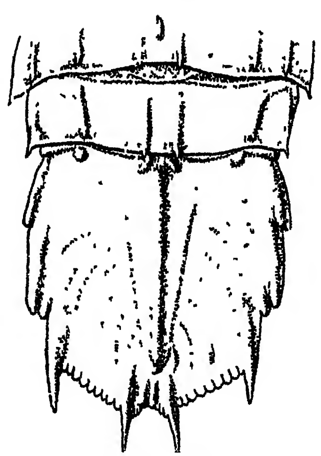

FIG. 3.—*Squilla affinis*

Squilla nepa was recorded from Auckland by Heller, but there has been nothing to indicate which of these two species was intended, and up till the present time no further specimen has been obtained by local collectors, and consequently the occurrence of this species in New Zealand has been considered doubtful.

Among the *Squillidae* in the Dominion Museum kindly placed at my disposal by Mr. Hamilton there is a single dried specimen which, though imperfect, evidently belongs to *S. affinis* Berthold as described by Bigelow. The eyes are imperfect, but there is sufficient of them left to show that they

were large, triangular, and with the corneal axis oblique, while the carinae on the carapace agree precisely with the description and figure given by Bigelow, and in themselves are sufficient to show that the specimen belongs to *S. affinis* and not to *S. nepa*. The specimen also agrees with his description in all the other characters that can be still seen. Unfortunately, the exact locality of this specimen is not known.

The species *S. affinis* is known from various localities in Japan and also from Hong Kong, and its occurrence in New Zealand indicates a distribution similar to that of numerous other marine *Crustacea*.

The species is described by Bigelow as follows: "A *Squilla* with large triangular eyes, the corneal axis being oblique and as long as or usually longer than the peduncular one and 0·05 times the length of the body: the outer margin of the dactylus of the raptorial claw not sinuate or only slightly so: 6 teeth on the dactylus; the rostrum slightly truncated, and supplied with marginal carinae and a median tubercle; 5 carinae on the carapace, the median one not bifurcated for more than one-fourth its length and the lateral ones continued into the anterior lateral spines, which do not reach as far forward as the suture between the rostrum and carapace, the posterior lateral angles evenly rounded; no ventral spine on the first exposed thoracic segment, its lateral processes and those of the next two segments bilobed as in *S. nepa;* submedian carinae present on all except the first segments of the hind-body: crest, keel, and symmetrical lines of pits on the telson and 6 marginal spines, 8 basal carinae, and between the former 4 to 5 submedian, 7 to 9 intermediate, and 1 lateral denticle."

I give a figure representing the telson. (See fig. 3.)

Genus Lysiosquilla Dana.

"*Stomatopoda* having the 6th abdominal segment separated from the telson by a movable joint; the hind-body depressed, loosely articulated,

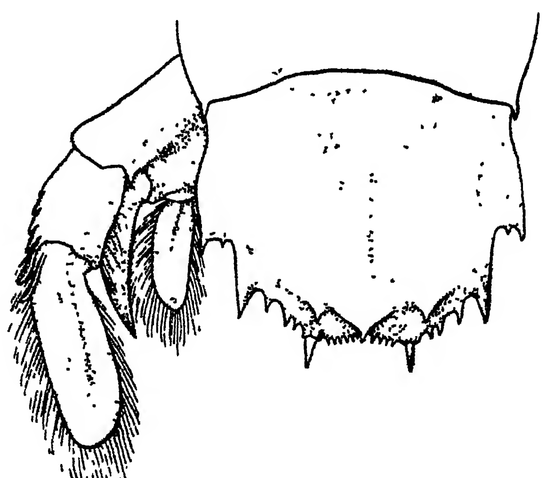

Fig. 4.—*Lysiosquilla spinosa:* Telson and uropod.

and wide; the dactylus of the raptorial claw without a basal enlargement, but with not less than 5 marginal teeth; no more than 4 denticles, and often

only 1, between the intermediate and submedian marginal spines of the telson, which is usually wider than long: and the outer spines of the basal prolongation of the uropod usually longer than the inner one." (Bigelow.)

Lysiosquilla spinosa (Wood-Mason).

Coronis spinosa Wood-Mason, Proc. Asiatic Soc. Bengal, 1875, p. 232. *Lysiosquilla spinosa* Chilton, Trans. N.Z. Inst., vol. 23, p. 61, 1891 (with synonymy).

This species is fully described in my previous paper quoted above. Since then I have seen specimens in the Otago Museum from Resolution Island, "dug in the sand" (R. Henry, 1900), and Stewart Island (T. J. Parker); one imperfect specimen was obtained during the cruise of the trawler "Nora Niven" (Waite), and quite recently Miss S. D. Shand has sent me a specimen from the Chatham Islands.

I give a figure of the telson and uropod for comparison with those of the other species.

Lysiosquilla brazieri Miers.

Lysiosquilla brazieri Miers, Ann. Mag. Nat. Hist. (5), vol. 5, p. 11, pl. 1, figs 3–6, 1880; Haswell, Cat. Aust. Crust., p. 206, 1882.

Two dried specimens in the Wanganui Public Museum, which have kindly been placed at my disposal by the Curator, Mr. H. W. Hesse, seem certainly to belong to this species, agreeing well with the figures and description given by Miers, except that there are only 10 spinules on each side on the posterior margin of the terminal segment instead of 14; there is also a slight median sinus.

As Miers pointed out, this species is evidently closely allied to *L. latifrons* De Haan, and the two specimens that I have been able to examine seem to connect these two species still more, for they bear only 10 minute spinules, as in *L. latifrons*, and there is a slight indication of a sinus on the posterior margin of the terminal segment; they agree, however, with *L. brazieri* in having the appendages of the last pair of thoracic limbs almost linear, while these are described as being ovate in *L. latifrons*.

I think there is probably little doubt that these two species should be combined, but as I have only two imperfect dried specimens, and am unable to consult any description of *L. latifrons* beyond that given by Miers, I leave the decision of this question open for the present.

A specimen of this species was sent to me in 1894 by the late Mr. S. H. Drew, then Curator of the Wanganui Public Museum, who informed me that in 1885 thousands were washed ashore at Otaki, the beach being strewn for miles after a heavy south-west gale, the animal never having been seen before or since. The specimen I then examined was a very imperfect one, and I was unable to identify it and merely recorded in my note-book that it differed considerably from *L. spinosa* in the arrangement of the spines on the terminal segments. The two specimens now examined are evidently from the same lot, having been obtained at Otaki in 1885 by Mr. Lee, and they have enabled me to identify the species as above. I have seen no other specimens.

L. brazieri is recorded from Port Jackson, New South Wales; *L. latifrons* from Japan.

ART. XIX.—*Stellerids and Echinids from the Kermadec Islands.*

By W. B. BENHAM, D.Sc., F.R.S.

[Read before the Otago Institute, 1st November, 1910.]

MR. OLIVER was good enough to place his collection of echinoderms in my hands for identification. In this communication I deal only with the Asterids, Ophiurids, and Echinids, and must leave the Holothurians for a later article. He also sent me useful notes on the colour and habitats of most of those collected.

A good number of species have already been recorded from these islands —some littoral forms by Farquhar (1898 and 1906), and others from the deep sea between the islands in the "Challenger" Reports.

The present collection contains twenty-one species, and includes all those recorded by Farquhar except *Pectinura* (*Ophiopeza*) *danbyi*, together with several species not hitherto met with at the islands.

LIST OF LITTORAL ECHINODERMS. (The new records are preceded by the sign x.)

Asteroidea.

x *Astropecten polyacanthus* M. & T.
Asteropsis imperialis Farq.
x *Gymnasteria lissotergum* sp. nov.
Asterina oliveri sp. nov.
Ophidiaster (?) *kermadecensis* sp. nov.
Asterias rodolphi Perr.
x *Asterias edmondi* sp. nov.

Ophiuroidea.

Ophionereis schayeri M. & T.
x *Amphiura squamata* D. Ch.
x *Ophiocoma brevipes* Pet.
x *Ophiothrix oliveri* sp. nov.
x *Ophiura kermadecensis* sp. nov.
Pectinura (*Ophiopeza*) *danbyi* Farq.

Echinoidea.

x *Centrostephanus rodgersii* Ag.
Toxocidaris tuberculatus Lam.
Tripneustes gratilla Ag.
Phyllacanthus dubia Brndt.
Echinometra mathaei Blnvl.
x *Plesianthus testudinarius* Gray.
x *Echinoneus cyclostomus* Leske.
x *Fibularia australis* Desmlns.
x *Brissus carinatus* Lam.

Of the Asterids, only *Astropecten polyacanthus* has been recorded from New Zealand waters, and there is some doubt as to this identification. All the six genera are widely distributed, and the species are closely related to Pacific and Australian forms. *Asteropsis* contains but two species—this one from the Kermadecs, and the other (*A. vernicina*) from Australia.

Of the six species and genera of Ophiurids, only two have been found on our shores—*Amphiura squamata* and *Ophionereis schayeri*—both of which are very widely distributed in the Pacific. The other genera are also common in this ocean.

Of the ten species of Echinids, belonging to as many genera, only two have been found on our shores, and this but rarely—viz., *Centrostephanus rodgersii* and *Toxocidaris tuberculatus*. The whole series is Indo-Pacific, and for the most part is common on the east coast of Australia.

In order to make this list as complete as possible, I here add those obtained by the "Challenger" at Stations 170 and 170A, at a depth of

520 fathoms, between Macauley Island and Sunday (Raoul) Island; and at Station 171, from a depth of 600 fathoms, north of the latter island. The species peculiar to these stations are marked with the sign x.

Asteroidea.

x *Solaster torulatus* Sladen.
x *Cribella sufflata* Sladen.

Ophiuroidea.

x *Ophioceramis* (?) *clausa* Lym.
,, *obstricta* Lym.
x *Ophiactis cuspidata* Lym.
,, *flexuosa.*
,, *nama* Lym.
x *Ophiacantha cornuta* Lym.
x ,, *vepratica* Lym.
Ophiomitra plicata Lym.
x *Astroschema horrida* Lym.
x ,, *salix* Lym.
x *Ophiomusium scalare* Lym.
Ophiophyllum petilum Lym.
x *Amphiura argentea* Lym.
x ,, *canescens* Lym.
x *Ophiochiton lentus* Lym.

Echinoidea.

Salenia hastigera Ag.
Aspidodiadema tonsum Ag.
x *Trigonocidaris monolini* Ag.
Echinus acutus Lam.

It will be seen that a very considerable proportion of these deep-water species are endemic; the others are Indo-Pacific. As Mr. Farquhar has already pointed out, the littoral fauna is not at all related to that of New Zealand, but is distinctly Indo-Pacific, with much affinity to the east Australian coastal fauna.

I have not thought it necessary to repeat the synonymy or the references to the earlier literature: both of these matters may be found treated at length in Farquhar's paper (1898).

ASTEROIDEA.

Astropecten polyacanthus Muller and Troschel.

One specimen dredged in 12 fathoms, on gravel bottom, west of Meyer Island (20/4/1908), and a second smaller one dredged in 20 fathoms in Denham Bay, Sunday Island (4/4/08).

The larger individual has the following dimensions: R 87 mm., *r* 15 mm.; so that R : *r* = $5\frac{4}{5}$. One ray is quite short and stumpy, being in the course of regeneration; of the original arm only 23 mm. remains, while the new tip is 12 mm. in length.

A small specimen, in which R 10, *r* 4, appears to be the young of this. It is, however, almost too small to be worth describing in detail. There is a single spine on each of the supra-marginals, but the infra-marginals carry only 2 spines in place of the 4 or 5 of the adult.

This is a widely distributed species, not hitherto recorded from the Kermadecs. It is said by Hutton (1872, p. 6) to occur on the New Zealand coast, but I have not seen a specimen.

Distribution.—Red Sea, Indian Ocean (Mauritius, Ceylon, India, Andamans), Pacific (Australia, China, Japan, Fiji, &c.).

Asteropsis imperialis Farquhar. Figs. 1–3.

Farquhar, Linn. Soc. Journ. Zool., vol. 26, p. 193, pl. 13.

I have before me, including the type, three stages in the growth of this species, which in some respects seems partly to bridge over the gap between

Asteropsis of Müller and Troschel and *Dermasterias* of Perrier (1875). Unfortunately, I have not access to Perrier's original paper, but I rely on Sladen's diagnosis of the two genera ("Challenger" Report, p. 355). One difference (I gather both from Sladen and from Bronn's "Thierreichs") lies in the presence of a distinct "composite reticulated meshwork" formed by the abactinal plates in *Dermasterias*, while the skeleton of *Asteropsis* consists of "irregular substellate plates not forming such a network." From the account of the largest specimens given below it will be seen that in the adult of this species such a "composite reticulated meshwork" does exist, but in other features the genera are quite distinct.

The material at my disposal consists of—(*a*) Large specimens, both dried and in alcohol; (*b*) Farquhar's type, which is of intermediate size: (*c*) small ones, dried.

(*a*.) The dried specimens are somewhat compressed and distorted, but the plates are pretty distinctly seen, while in those preserved in alcohol the skeleton is entirely concealed by the tough skin, which is wrinkled on the abactinal surface, and especially near the tips of the rays, but is smooth on the actinal surface. This skin encloses and connects the adambulacral spines so as to form 2 thick membranes on each side of the groove, one lying in the furrow, the other along its margin.

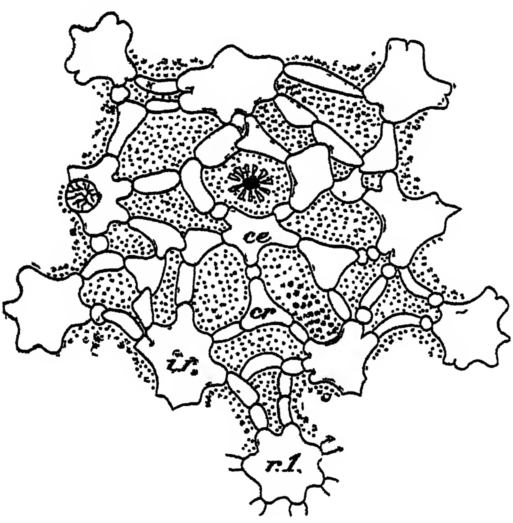

FIG. 1.—*Asteropsis imperialis*.
The central portion of the disc (× 2). *ce.*, central; *c.r.*, centro-radial; *i.r.*, interradial; *r.1.*, primary radial.

Dimensions.—The dried specimens measure R 75, *r* 34; R 70, *r* 31. The alcoholic specimen gives R 56, *r* 24. Thus *r* : R = 1 : 2·20 to 2·33. The form is stellate, with rounded interbrachial angles. The rays are broad at the base (3 mm.), tapering gradually to a rounded apex. At about midway along the ray is 15 mm. across. The figure given by Farquhar represents well the general appearance of a preserved specimen.

The madreporite is prominent and round, situated rather nearer to centre than to the margin (as 12 is to 20). The anus is surrounded by a circle of short cylindrical spines, about 10 in number, which close over it.

The abactinal skeleton forms an open meshwork, with large papular areas, separated by short rows of narrow flattened ossicles about half as wide as they are long, which radiate from a series of 5- or 6-lobed plates at the nodes of the network. There is a 5-lobed central plate with the anus close to one side; from it radiate outwards short rods, forming a series of wide meshes around it. At the interradial margin of this circle are 5 irregularly stellate plates, one of which bears the madreporite.

These are the primary interradials. Each presents 5 lobes proximally and a large single or feebly notched lobe distally. From the latter a series of paired plates lying side by side pass outwards to the interbrachial margin. At intervals along this double row there are semi-stellate plates with radiating rods on either side (fig. 2).

Outside the interradials is a series of 5 primary radials at the base of the rays. Each is a more or less rosette-shaped plate with 5 to 7 lobes. Along the middle of the ray is a series of similar plates connected together by short rods, which in the distal region of the arm become shorter and shorter. so that the median rosettes come to lie closer together (fig. 2).

Along each side of the radials or median row is a lateral series of similar rosette plates, but of less size; these, however, cease about half-way along the arm. They are connected to the median rosettes by short narrow rods, and when the intermediates cease the rods become broader and shorter, and connect the medians with the supra-marginals. Still further out the radials themselves touch the marginals.

The supra-marginals are large, irregularly oval or pyriform, or even subtriangular. with rounded angles; they are very convex outwards, and are obliquely placed and loosely articulated. I find 11 or 12 along each side.

The infra-marginals have the same general form, but are rather smaller, with the longer axis longitudinal; and, though usually immediately below the supra-marginals, the number is rather greater—12 or 13 (fig. 3).

On the upper surface there are the characteristic "valvate pedicellariae" at the base of each arm; they are of large size, measuring 4·5 mm. in length. As Farquhar has noted, these are not quite regularly arranged —not always paired—as will be seen from the following table (A and B are large, C and D are young forms): —

Specimen.	Ray.	Pedicellariae.
A ..	1	Paired.
	2	Paired, though unsymmetrical.
	3	Two on one side, none on the other.
	4	Paired.
	5	One on one side, none on the other.
B ..	1	One only.
	2	None.
	3	Paired.
	4	None.
	5	One small one, on one side only.
C ..	1	Paired, with a 3rd smaller on the disc, near median plates.
	2	Paired.
	3	One.
	4	,,
	5	,,
D ..	1	Paired.
	2	,,
	3	,,
	4	,,
	5	One.

FIG 2

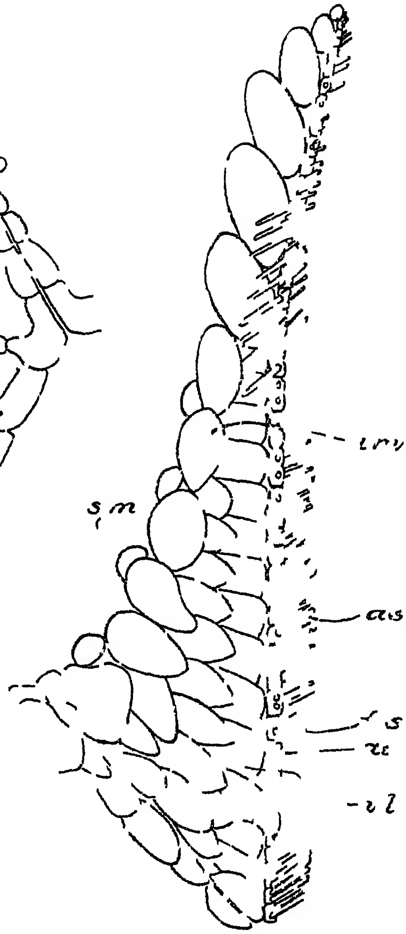

FIG 3

Asteropsis imperialis

Fig 2 Abactinal surface of half a ray (× 2) denuded of its skin showing the arrangement of the skeleton The dotted lines are diagrammatic only, for the purpose of showing up the plates more distinctly *c*, connective *ce*, central *cr*, centro radial, *d l*, dorso lateral *i r* interradial *rl* primary radial *s m* supra marginal

Fig 3 Actinal surface of half a ray (× 2) In the proximal region the paired actinal ambulacral spines are inserted, in the middle, both the furrow spines and the single actinals which are present here toward the distal extremity the actinal spines are removed and only the furrow spines are shown *ad* adambulacral *as* actinal ambulacral spine *f s*, furrow spine *i m* infra marginal *s m* supra marginal, *v l*, ventro lateral

The papular areas are occupied by numerous papulae

The actinal skeleton in the interbrachial area consists of more or less oval imbricating plates, with the longer axis radially directed There are no pedicellariae on this surface

The adambulacral armature is formed by 2 rows of spines the furrow series of 2 spines to each ossicle cylindrical blunt pointed, and close together, the actinal spines (or outer series) are broader more conical and also bluntly pointed In the proximal half of the arm there are 2 actinal spines to each ossicle but further out 1 only

(*b*) By the kindness of Mr Edgar Waite the Curator of the Canterbury Museum, I have been allowed to examine the type of the species It is in much better condition than mine as it has evidently been carefully dried, and the skeletal plates are not disturbed It has faded to a dirty yellow colour

The disc plates are quite distinctly seen through the skin the chief ones are lobed as in the above specimens, and are connected by short ossicles so as to form a network, but the width of the meshes is smaller the length and number of rods being less than in the above The distinctly lobed or rosette plates on the arm both median and lateral have the same arrangement, and there are the same interbrachial lines of plates Mr Farquhar's figure was drawn I suspect from the wet specimen, so that the plates are not clearly shown

I may note that on one side of one arm, which bears a normal pair of pedicellariae there is a trivalved pedicellaria as shown in Farquhar's figure situated just in front of one of the normal bivalved pedicellariae, and symmetrical with a small bivalve on the opposite side of this arm

(*c*) In the small individuals the short rods connecting the rosette plates are still fewer or absent so that the plates are in contact The supramarginals touch the radials for about half the length of the arms then there is a single row of intermediates On the disc the plates are imbricated

The dried specimens measure R 45 / 20 and R 40 / 19

Colour —The colour in life is described by Mr Oliver as bright red the dried ones are still carmine red those in alcohol are bright orange

Locality —Oliver states that they are "not common" They occur on rocks near and below low water mark Meyer Island (29/2/1908), Boat Cove Sunday Island (1/5/1908) Farquhar's specimen also came from here

Distribution —The genus is represented by *A vermicina* on the Australian coast For the opportunity of comparing the Kermadec species with this I am indebted to Mr Etheridge Curator of the Australian Museum who was good enough to send me specimens of the Australian species

Gymnasteria lissotergum sp nov Figs 4 and 5

Three small starfishes seem to require the formation of a new species

Dimensions —R 11 / 6 5 The smaller has R 6 / 4 The ratio r R is 1 1 84 and 1 1 5

Flat star shaped with broad arms (7 mm at the base), rounded at the tip The abactinal surface is covered with flat roundish hexagonal plates of relatively large size pavement like in their arrangement, and covered by a rough finely granulated skin Papulae occur in lines between the plates

The median radial plates are somewhat larger than the laterals, which extend to the tip of the ray. The madreporite is single, small, about half the diameter of any of the other plates of the disc, and situated close to the centre.

Marginals well developed. The supra-marginals are large, flat, squarish, lying on the upper surface. There are 7 on each side, excluding the terminal. In one specimen some few of the supra-marginals bear 1 to 3 quite small blunt spines on the outer edge. In the other specimen they are little evident.

In each interradius a couple of plates, with adjacent sides straight, extend from the primary interradial to the marginals.

At each side of the base of the arm is a small valvate pedicellaria, though not quite regularly disposed, as it may be absent from one side. They are usually carried on one of the small supplementary plates, between the supra-marginal and laterals. In one case there is a pedicellaria on a special plate close to the median row.

On the actinal face the interbrachial areas are formed of small plates similar to those of the upper surface. There are no pedicellariae or papulae on this surface.

The infra-marginals are similar in form and number to the supra-marginals. Each bears a horizontal row of 3 or 4 short conical spines, compressed from above downwards, closely set along the outer edge of the plate. In each group the 2 middle spines are rather longer than the 2 outer ones. There is a gap between the groups, so that the saw-like fringe is interrupted.

The adambulacral armature: The series of furrow-spines and the series of actinal spines are united together to form a sort of membrane, so that the groove is margined by 2 membranes on each side. The furrow-spines are 2 to each plate, cylindrical; the actinal spines are solitary over the greater length of the groove, but duplicated on the plates near the mouth, flattened and broad, with very blunt points. There are no special teeth at the oral angles.

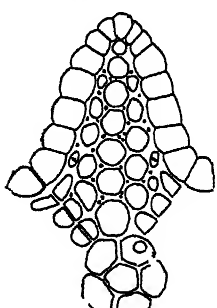

Fig. 4.

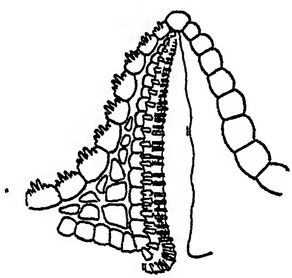

Fig. 5.

Gymnasteria lissotergum.

Fig. 4. The abactinal surface of the disc and of one ray (× 3).

Fig. 5. The actinal surface of one ray (× 3). Details are inserted on one side only.

Colour.—Mr. Oliver gives the colour as "bright red." When dried they are pale buff, with indications of a richer brown near the apex.

Locality.—Meyer Island: Under stones in rock-pools (19/5/1908): and one was dredged "on coral, 3 fathoms" (1/3/1908).

Distribution.—The genus is Pacific and Indian.

Remarks.—The juvenile form of *G. carinifera* v. Martens, figured by Sladen ("Challenger" Report, pl. 52, figs. 5–8), differs from the present species in the relatively greater size of the plates, in the presence of large spines on the infra-marginals, and none, or very small ones, on the supra-marginals;

also, in that species there are 2 rows of lateral intermediate plates separating the radials from the marginals, while the proportion $r : R$ is different. The arms are blunter, and the adambulacral armature different.

Asterina oliveri sp. nov. Fig. 6.

Of this starfish, which is very common in rock-pools, I have nine specimens, all dried. They have, unfortunately, been a good deal flattened, and the spines rubbed off in places, but the general characters are readily seen by comparison of one with another.

Dimensions.—The largest is R 27, r 23, and from a series of measurements it is found that $r : R$ is about 5 : 7.

The outline varies from stellate to nearly pentagonal, with only slight incurvatures between the rays. Probably in life the centre of the disc is elevated, but it is now depressed. The arms are, naturally, broad, and end bluntly. The madreporite is single, not prominent, much nearer to the centre than to the margin, its mesial edge being a little more than half its own diameter from the centre.

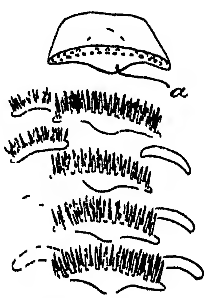

FIG. 6.—*Asterina oliveri.*

A few of the radials and latero-dorsals, on some of which the double rows of spines are shown; one radial is wholly exposed, but of the others only the narrow spiniferous margin is visible (a).

The abactinal plates are crescentic, those along the middle of the ray longer than elsewhere, so that they are distinctly conspicuous. On either side of this row the plates are shorter, and this decrease continues towards the middle of the interbrachial area. The spines are in 2 rows on each plate, closely set, cylindrical, fine, and sufficiently long to reach nearly to the neighbouring plate when pressed down.

There are about 14 spines in each row on the mesial (radial) plates; about 10 on the curved interradials of the interbrachial area, but towards the margin they get fewer, there being only some 5 or 6 on these smaller plates.

On the actinal surface each plate carries only 1 spine, shorter than those of the abactinal plates, and a good deal stouter; but on the 5 or 6 rows of plates near the margin, where they are reduced in size, each plate bears 2 spines. The colour of these actinal spines is greenish-blue, with white tip and white base.

The adambulacral armature: The furrow-spines are 2, cylindro-conical, standing side by side in a row. Externally on the actinal face each plate carries 1 spine, longer and stouter, blunt-pointed, and somewhat flattened.

The oral armature: Each interradial couple bears 10 spines (*i.e.*, 5 on each side), arranged horizontally close together. Of these, 4 are long, stout, flattened, and truncated, with 3 on either side rather stouter.

Each of the oral plates, at the angle, bears a single spine on its actinal surface.

Colour.—In life they are black, but in the dried state they are a uniform dark bluish-grey. The lower surface is bluish-green, the spines here being greenish, with white tips.

Locality.—On the east coast of Sunday Island; common; rarely noticed elsewhere.

Remarks.—This species differs from our New Zealand *A. regularis* in several points: the spines on the upper surface are finer and more numerous, while in that species also the radials are not prominent. I may state that a good account of our native species is a desideratum, for it exhibits some variations. No one has recognized again Perrier's *A. novae-zealandiae*, which appears to be a variation only. All the Kermadec individuals have 5 arms, whereas *A. regularis* is well known to present 5, 6, or even 7 arms.

This new species is allied, I think, to *A. gunnii* Gray, from the coasts of Australia, Tasmania, and the Cape of Good Hope, which, however, is apparently invariably 6-rayed, and the actinal surface of the adambulacral plates bears 2 spines. Owing to lack of necessary literature I give it a new name, though I am quite prepared to find that this species has already been described.

Ophidiaster (?) kermadecensis sp. nov. Figs. 7-11.

The material consist of several dried individuals, as well as three in alcohol.

Dimensions.—R 82, *r* 12; so that *r* : R is nearly 1 : 7. The diameter of the arm about half-way along is 12 mm.

The rays are long, subcylindrical, tapering to a point. The abactinal skeleton is composed of rounded and round-topped plates, covered with

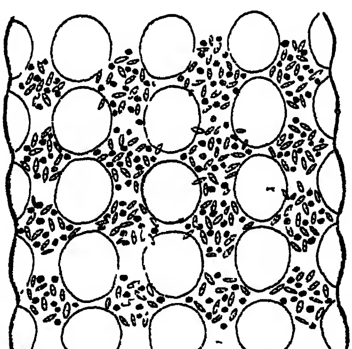

Fig. 7.

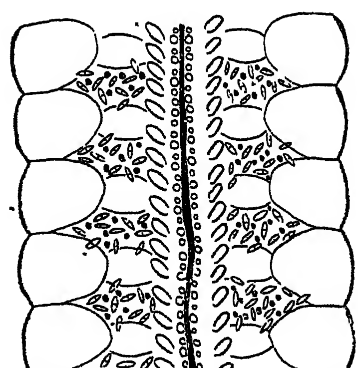

Fig. 8.

Ophidiaster (?) kermadecensis.

Fig. 7. A portion of a ray, abactinal surface (× 4). No attempt is made to show the granulation of the skin, nor the fact that the papular areas are depressed below the level of the upper surface of the plates, which have their outlines too sharply marked in the figure.

Fig. 8. A portion of a ray, actinal surface (× 4). See remarks under previous figure.

a tough skin presenting small, unequal-sized, closely set, low, rounded granulations, so that the skin looks shagreened.

There are 7 rows of plates, all practically alike in form and size—that is, a median (radial), a lateral (adradial) on each side, and the two marginals.

The papular areas are large, and are continuous with one another in a longitudinal direction. Numerous pores, as many as 15 to 20, are

scattered over each area. The granulations of the skin of these areas is finer than on the plates.

Characteristic pedicellariae (those termed by Perrier "pédicellaires en salière" and by Sladen "entrenched"), in the form of shuttle-shaped pits are likewise scattered over the whole of these areas in considerable numbers: I counted as many as 15 to 20 in some areas. They are, however, not confined to these places, but encroach upon the edges of the plates. They are set close together, almost touching, with their long axes in all directions (fig. 11).

The plates on the disc have the same arrangement as in *Ophidiaster ophidianus*, as described and figured by Ludwig (1897). The circular madreporite is larger than the interradials, and a little nearer the margin than to the centre.

The actinal surface is covered by the same skin as the upper surface. The adambulacral plates are separated from the infra-marginals by a single row of small plates (the ventro-laterals), every alternate plate being connected with a marginal by an upwardly directed process, while the other plates are horizontally arranged. Papular areas with pedicellariae

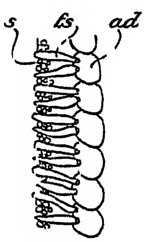

FIG. 9.

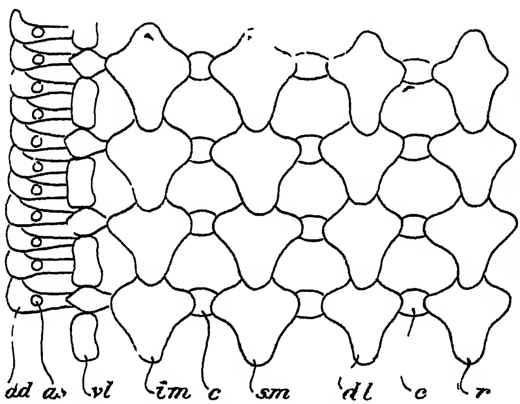

FIG. 10.

FIG. 11.

Ophidiaster (?) *kermadecensis*.

Fig. 9. A portion of the side of the ambulacral groove, seen from mesial aspect after the removal of the opposite wall (× 4). *ad.*, adambulacral; *f.s.*, furrow-spine; *s.*, the granulations of the skin pushing between the furrow-spines.

Fig. 10. The skeleton of one side of portion of a ray (× 4) after treatment with potash and somewhat flattened out. *ad.*, adambulacral; *a.s.*, pit for actinal ambulacral spine; *c.*, connective; *d.l.*, dorso-lateral; *i.m.*, infra-marginal: *r*, radial; *s.m.*, supra-marginal; *v.l.*, ventro-lateral.

Fig. 11. An "entrenched pedicellaria" (much enlarged).

occur outside the latter. The adambulacral armature presents 2 furrow-spines on each plate, closely pressed against the side of the furrow, with the tips outwardly directed. The granular skin pushes furrowwards between them. The actinal spines are much thicker, shorter, and stouter, and somewhat clavate in form. There is one to each plate.

As Sladen mentions "super-ambulacral plates" in his diagnosis of *Ophidiaster*, as opposed to some other genera of the family, I examined into their occurrence here: they exist as short rods passing from the upper surface of the ambulacrals to the ventro-laterals.

Colour.—In life this species is deep orange. Mr. Oliver remarks, "Its colour renders it very conspicuous, and it does not try to conceal itself. This seems to be a good case of 'warning coloration,' the starfish evidently being distasteful to fish," &c. I do not know whether he made any experiments to support this suggestion, which on the usual view of coloration seems plausible. When dried the colour turns to a dirty pale orange-brown; in alcohol to chocolate-brown.

Locality.—Meyer Island (20/5/1908). It has already been recorded and sufficiently described from Raoul (Sunday) Island by Farquhar (1897), who did not give it a specific name.

Remarks.—I have doubts as to whether this is really an *Ophidiaster*, for according to Ludwig's analysis of the skeleton (1897) of the Mediterranean species, *O. ophidianus*, there should be 2 rows of ventro-lateral plates. I do not know whether a similar careful analysis has been made for other species, but Ludwig lays stress on this point, for he separates, under Gray's name *Hacelia*, *H. attenuata* on account of the presence here of 3 ventro-laterals. Possibly, therefore, the Kermadec species deserves a new generic title.

The arrangement of the arm-plates in 7 regular longitudinal rows is a characteristic of *Ophidaster* which is shared by *Hacelia*, whereas in *Linckia* the dorsal arm-plates are not regularly disposed, though in a recent paper Koehler (1910) describes *L. dubiosa*, in which the dorsal surface has the appearance of *Ophidiaster*, while the arrangement of the adambulacral spines in contiguous rows is held to be a feature of *Linckia*.

I have been rather puzzled by the "entrenched pedicellariae," for in Bronn's "Thierreichs," as also in Delage's "Zoologie Concrète," the diagnosis of *Ophidiaster* includes the "absence of pedicellariae." Nevertheless, Sladen describes two species (*O. tuberifer* and *O. heliostichus*) in which these are present, and Ludwig adds several others with "pédicellaires en salière." This diagnosis is thus misleading, for it is one of the apparent distinctions between this genus and *Linckia*.

I am not sufficiently familiar with the literature to do more than express my doubts as to the validity of referring this Kermadec species to the genus *Ophidiaster*. I am informed that a specimen was sent to Professor Bell, of the British Museum, for identification, and it was stated by him that he did not know the species, and that it was probably new to science: hence the detailed account above given. At the same time, I have not seen Perrier's account of *O. germani*, from Lord Howe Island and New Caledonia, and it may turn out to belong to this species, or to one of Lutken's from Tonga.

Asterias rodolphi Perrier.

Perrier. Ann. Mag. Nat. Hist. (4), vol. 17, p. 34 (1876).

Farquhar (1897) has already given a full description of this species, which was collected at Raoul (Sunday) Island, where the type was found so far back as 1854.

The present collection was made at Sunday Island "under stones at low-water mark." It consists of seven specimens in alcohol. They all have 7 arms.

Measurements were made on three individuals, with the following result: R 95, r 18; R 80, r 14; R 48, r 8; hence the ratio R : r is between 5 and 6 : 1.

Colour.—In life the starfish is dark purple; in alcohol it is pale red with the interbrachial areas dark brown.

Asterias (Stolasterias) edmondi sp. nov. Figs. 12 and 13

Two dried specimens and one in alcohol appear to require the formation of a new species, and I give it the above name in commemoration of the great work of Edmond Perrier on the echinoderms.

Dimensions.—R 33, *r* 7; and R 26, *r* 5·5. The larger has 8 rays, the smaller 7.

The remarkable feature about this species is the naked central area, provided with only a few scattered small plates. It recalls *S. alexandri* Perrier (1905); but in that species the naked area is traversed by 5 radial rows of small plates, even when young.

The arms are long and narrow, being in the larger individual 5 mm. across the base; so that L : B equals 28 : 5—*i.e.*, its length is more than five times its breadth.

The whole starfish is much more delicate in build than *A. rodolphi*. The central abactinal region is almost bare, appearing as a thin membrane

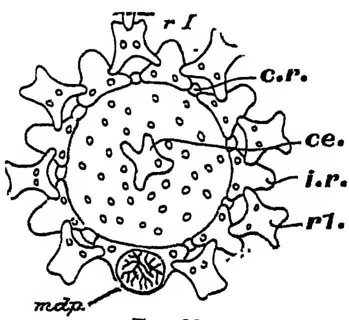

FIG. 12.

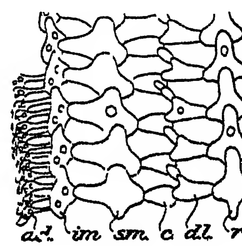

FIG. 13.

Asterias edmondi.

Fig. 12. The central area of the disc (× 4). *ce.*, central; *c.r.*, centro-lateral; *i.r.*, inter-radial; *mdp.*, madreporite; *r1*, primary radial.

Fig. 13. The skeleton of a ray, half only (× 4). *ad.*, adambulacral; *c.*, connective; *d.l.*, dorso-lateral; *i.m.*, infra-marginal, *s.m.*, supra-marginal; *r.*, radial.

with minute, isolated, roundish plates or granules roughly arranged in 3 or 4 incomplete concentric circles. In the larger one there is in the centre a quadrilobed plate (the central) bearing a spine, which plate is absent in the smaller specimen. The diameter of this area is 5 mm. It is surrounded by a ring of more or less pentagonal or quinque-lobed plates, interradial in position (*i.r.*), each bearing 2 spines. One of these is, of course, the madreporite, which is relatively of large size. Lying outside this circle are the 7 primary radials. The radials are 3-lobed, 2 lobes being proximal and resting on the *i.r.* Between the *i.r.*, and almost entirely concealed by them, are the centro-radials.

The arm-skeleton consists of a median series of triradiate plates, every alternate one bearing a spine, and, like all the spines, these are surrounded at their base by a cushion of pedicellariae.

On each side of the median series is a row of transversely arranged plates, slightly lobed at the outer end, each of which is connected by means of one or two smaller plates with 2 vertical rodlike plates. These in their turn

abut upon the upper end of the large supra-marginals, every third of which bears a spine, which projects laterally, forming a fringe along the side of the arm. The infra-marginals are horizontally extended, each bearing 2 spines, obliquely set, one slightly above the other. The spines are cylindrical, short, and relatively stout, with rounded roughened tip, those at the margin somewhat flattened from above downwards.

The adambulacral armature consists of a single series at the proximal portion of the groove (about one-third of its length), but further away from the mouth each plate bears 2 spines, the inner being slenderer than the outer, but of the same length.

The individual in alcohol has 3 small regenerating arms.

Colour.—In life it is bright blue; when dried it is pale grey.

Locality.—Cast up on Denham Bay beach, Sunday Island; and also found under stones below low-water mark at Coral Bay.

Remarks.—I find no reference, in the literature at my disposal, to any starfish of this subgenus *Stolasterias* having a naked central area; but, as I have mentioned, *S. alexandri* is nearly naked at this point. It is a curious exception to the general rule of development of the plates of the disc formulated by Ludwig that the centrale is the first to appear—at any rate, in the Mediterranean species.

I may state that I have a very small specimen of *A. calamaria*—less than the smaller of the two above described—in which the disc-skeleton is already well developed.

Ophiuroidea.

Oliver writes, in explanation of the condition of the Ophiurids, "I had great difficulty in preserving the brittle stars and holothurians; they were all obtained at Meyer Island or at Coral Bay, and often two or three days would elapse between the time the specimens were collected and my return to camp, so I was forced to put them into spirit before they were quite dead, with the result that they broke themselves up."

Ophionereis schayeri Muller and Troschel.

This species has already been recorded from the islands by Farquhar (1906). Oliver states that it is "very common in sand and mud, under stones, in rock-pools, and about low-water mark."

This common New Zealand brittle star is highly variable in coloration, which Farquhar has suggested may be protective. This author has given a full account of its anatomical features (1894) and a list of references (1898), and in another paper its distribution (1906), so that I need not add anything further.

Locality.—Meyer Island; and elsewhere on these islands (Haylock).

Distribution.—New Zealand (from Auckland to Dunedin), Chatham Islands, Australia (east coast), Tasmania, Juan Fernandez, and probably Galapagos.

Amphiura squamata Delle Chiaje.

I have given the full synonymy and references in my report on the Echinoderms from the subantarctic islands (1909); but recently Lyman Clark (1909) has suggested that this southern form—at any rate, that from Australia—is a distinct species, and places it in the genus *Amphipholis* (= *Amphiura*) as *A. australiana*. But if it turns out that our New Zealand

species is identical with that from Lord Howe Island it seems to me that Hutton's name *parva* (1879) should take precedence of Clark's. I have not re-examined the identity of our form.

The specimens collected by Mr. Oliver are juvenile: the largest of the five individuals measures 2 mm. across the disc; the arms are about $3\frac{1}{2}$ times this diameter.

Locality.—Coral Bay, Sunday Island: "In mud, under stones."

Distribution.—New Zealand, Auckland Islands, North Atlantic, Mediterranean, Cape of Good Hope, south-east Australia, Chile, Gough Island, Lord Howe Island.

Ophiocoma brevipes Peters.

I believe this to be Peters's species, but, as a detailed account is not accessible to New Zealand naturalists, I append a full account of these specimens.

The material consists of two specimens in alcohol.

Dimensions.—Disc, 28 mm. in diameter; arms, about 100 mm. from the base, but, as they are curled a good deal, it is impossible to give accurate measurements. The breadth of the arm at the base is 5·5 mm., and over the spines 11 mm.

The whole of the circular disc is covered with a thinnish skin, with minute, closely set, rounded granules, about 8 or 9 in the length of a millimetre. The disc bulges between the arms, which are set at the edge, and are not inserted in a notch.

The adradials are entirely covered, as is also the interbrachial actinal area, with this granulation.

The orals are large, hexagonal, with curved sides: sometimes the angles are obsolete. The radial diameter is a little greater than the transverse (L = 3·5 mm.; *br* = 3 mm.). The greatest breadth is near the outer side, and the mesially directed angle is acuter than the aboral angle.

The side mouth-plates are triangular, project externally, and are dark in colour. Buccal papillae pale, 5 on each side: the outer ones are long, conical, and pointed at the apex, the inner ones are slightly shorter and rounder.

Dental papillae form a somewhat triangular group, of which one series of 4 are quite small, and lie more superficially than the buccal papillae: 2 others are nearly in line with the latter, and similar to them in shape: 8 or 9 others form two curved rows below: of these, 4 or 5 lie in an upper row, the 2 outer ones of which are smaller than the other 3; while the lower row consists of 4, about equal in size, and arranged so as to alternate with those of the upper row. There is some variation in the details, even at the five angles of one and the same individual, especially with regard to the outermost series, which may be absent: while, on the other hand, there is sometimes an additional pair of small ones in line with the buccal papillae.

Teeth are 4 in number.

Upper arm-plates are twice broader than long, transversely oval, with convex distal margin; they meet one another broadly.

Under arm-plates are somewhat shield-shaped—that is, quadrangular, with the proximal margin less broad than the distal. The latter is convexly rounded and the lateral margins more or less excavated, while the

proximo-lateral angles are bevelled off. The length of the plate is about equal to the breadth of the distal margin.

The side arm-plates just appear dorsally and ventrally.

There are 2 tentacle-scales.

The arm-spines are usually 4, over the greater part of the arm, but near the base may be 5 or even 6, while in the distal portion the number sinks to 3. The spines are flattened, smooth, bluntly truncated; the upper two are shorter and broader than the lower two.

In one individual I noted that for two-thirds of the arm there are 3 spines, and 4 nearer the base; the 3 are subequal, but the middle one is slightly the longer. Towards the base the uppermost (the 4th) is broader, shorter, and flatter, and truncated. The upper spine is equal in length to about 2 upper plates; the lowest to nearly $2\frac{1}{2}$ plates.

Colour.—The colour in alcohol is very dark brown, nearly black, with many small pale spots (or, rather, dots), more or less circular, closely set, rather more densely and of larger size near the centre, and often disappearing towards the base of the arms. They are fewer over the adradials, especially along the middle of each, so that here there is a linear dark space. The arms are sometimes neither spotted nor banded, except towards the tips. The upper arm-plates are almost black, but in one individual the arms are banded. The arrangement is as follows: A few of the plates at the base of the arm are marked with a central cream-coloured oval spot, larger or smaller, at irregular intervals, but generally 2 or 3 such plates occur consecutively. Further away from the disc groups of 2 or 3 plates may be nearly wholly of this creamish tint, separated by more or fewer dark plates. Still nearer the tip groups of 3 or 4 plates are marbled with cream, and the intervening ones are grey, with dark margins, so that the ends of the arms are crossed by pale and darker bands. The actinal interbrachial areas are similar to the actinal surface, but the spots are larger and closer, so that this region appears paler, and there results a dark network on a pale ground. The orals and side mouth-plates are dark brown, but the madreporite is cream-coloured. The under arm-plates are pale brown, but close to the disc are cream. Some of the spines have a pale streak along the upper and lower margins.

Locality.—Coral Bay; in mud, under stones.

Distribution.—Lord Howe Island (Clark, 1909), Philippines, Pelew Islands (Lyman, 1874), Amboyna and New Guinea (Clark, 1908), Kingsmill Islands (Lyman), Sandwich Islands (Lyman, *O. insularia*).

Ophiothrix oliveri sp. nov. Figs. 14-17.

Material: Three specimens.

Dimensions.—Diameter of disc, 14 mm.; length of arm, about 82 mm. therefore the arm is about six times the disc-diameter.

General Colour.—Violet, with paler under-surface: when in alcohol, very dark: when dried, much paler.

The disc is pentagonal, with excavated interradial edges when dried, but bulging here when in alcohol.

The abactinal surface is covered with a thin skin, strengthened by small conical granules, which when dried are seen to be glassy spinules terminated in 3 or 4 (rarely 6) points, the length of the spine being about three times its breadth.

The adradial, the blunt tip of which is free and slightly raised, is also covered with spinules, though more sparsely than elsewhere.

The actinal interbrachial area is naked except for a small triangular patch of spinules which encroach from its margin.

The orals are remarkably small, and only that carrying the madreporite is at first noticeable, owing to its larger size. They are transversely rhomboid, situated close to the outer margin of the actinal region, near the genital clefts, leaving the whole of the angle-pieces, as well as the conspicuous perforation between them, exposed.

The torus is broad. There are no buccal papillae, but a large series of 16 dental papillae, which form a vertically oval patch, arranged in four horizontal rows of 4 in each row.

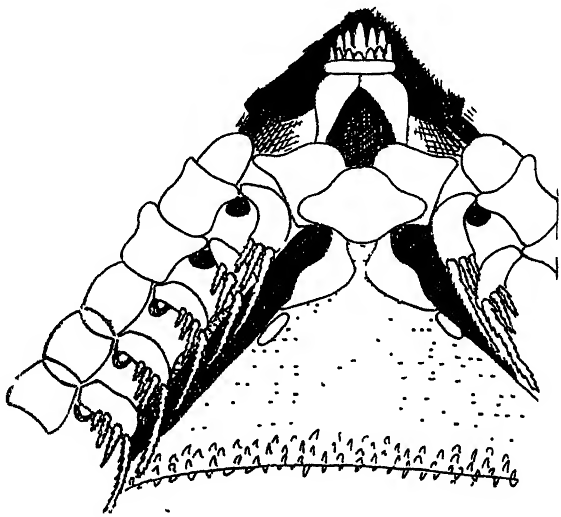

FIG. 14.—*Ophiothrix* [illegible].
Actinal surface of portion of the disc (× 5).

The upper arm-plates are naked, transversely oval, with the proximal margin straight. This margin has a raised median prominence, pale in colour, while the distal margin has a small peak, also pale. The successive plates are in contact (fig. 15).

The under arm-plates are subquadrate broader than long, the proximal margin nearly straight, the distal concave, the lateral borders convex (fig. 17).

The arm-spines are 8 in number, glassy, flattened, and feebly thorny along the edges. The lowest spine (1st) is the smallest, being only a little longer than the scutellum or tentacle-scale, just outside which it lies. The next 2 are successively longer, while the 4th, 5th, and 6th are the longest: these approximately equal four lengths of a dorsal arm-plate. The 7th and 8th are successively shorter; the 7th is nearly twice the breadth of a dorsal plate, while the uppermost is rather less than the length of this plate. The spines are violet (fig. 16).

The arms are (in alcoholic specimens) coloured with violet bands, alternating with paler, somewhat greenish, bands of less width. The violet

bands occur over the whole of one plate and the half of each of the two neighbouring plates, fading out gradually. The pale band occupies one plate. In the dried specimen the arms are uniformly violet dorsally.

Locality.—In sand under stones near low-water mark, Coral Bay, Sunday Island (July, 1908). Not common. Nothing is said of the colour when alive.

Remarks.—I supposed for some time that this was *O. caespitosa* Lyman, which was obtained at Port Jackson during the "Challenger" expedition; but from this it differs in (1) the absence of combs at the base of the arm, of which, however, no mention is made in the text, though in the figure

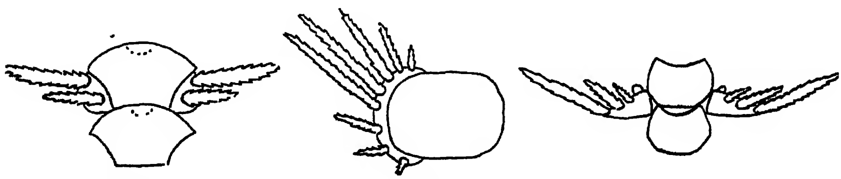

FIG. 15. FIG. 16. FIG. 17.

Opiothrix oliveri.

Fig. 15. Two upper arm-plates, lateral plates and spines (× 4).
Fig. 16. Transverse section of an arm, showing the series of spines on one side (× 4).
Fig. 17. Two lower arm-plates, with lateral plates and spines (× 4).

they are shown; (2) in the form of the under arm-plates; (3) the proportional lengths of the arm-spines; (4) the colour is said to be faint greenish above (in alcohol), the arms banded with lighter and darker yellowish-brown. It is also distinct from *O. coerulea* Hutton.

Variety.

Two specimens, also from Coral Bay, differ in one or two features, which do not appear to be of specific importance.

Disc, 8 mm. in diameter; arms, about six times as long.

In alcohol they are purplish-red; when dried the disc is very pale purple: the arms are marbled with white spots on a reddish, or in some places purplish, ground, though about every 3rd or 4th dorsal plate is uniform reddish. The spinulation of the disc is less profuse, so that the outlines of the plates are recognizable, and the interbrachial patch of spinules on the actinal surface reaches to the orals.

The under arm-plate is somewhat angular at its lateral margin, instead of being a convex curve.

The oral is longer, in a tangential direction, in proportion to its radial diameter, and the sides a little more excavated.

Although the disc is smaller than in the type, the width of the arm is much greater than in that.

The number of dental papillae is 12, though perhaps some smaller ones were overlooked.

Ophiura kermadecensis* sp. nov.

I have three dried specimens, of which one is quite small; the other two of about the same size, with a disc-diameter of 4 mm.; the arm is 7 mm.

* I have used *Ophiura* Lamk. (= *Ophioglypha* Lyman), in accordance with Bell's demonstration of its historical usage. He has shown, too, that Lyman's usage of *Ophiura* (= *Ophioderma* Müll. & Tr.) is wrong. Both Bronn's "Thierreichs" and Lyman Clark follow Bell (Ann. Mag. Nat. Hist. (6), viii, 1891, p. 339).

in length, but the tip is broken, so that probably it is really twice the diameter of the disc. There are also four other specimens in alcohol.

The circular disc is covered with larger and smaller subcircular plates. There is a distinct centrale, with convex roughened surface, surrounded by 5 quite small interradial scales, and then 5 larger radial plates, flat, but with the distal margin somewhat raised, so as to form a convex prominence; coloured pinkish. These radial plates are separated from one another by interradial rows of small convex plates. An outer circle of 10 flat plates, with prominent outer margins, radially and interradially placed with 1 or 2 small convex plates between them. The adradials of 2 neighbouring arms are separated by 1 large subquadrate plate (fig. 20, *m*), with its longer axis tangential and the outer border somewhat raised; and 3 or 4 smaller plates along its mesial margin separate it from other plates of the disc. In one specimen the number of smaller plates on the disc is less than in the one figured.

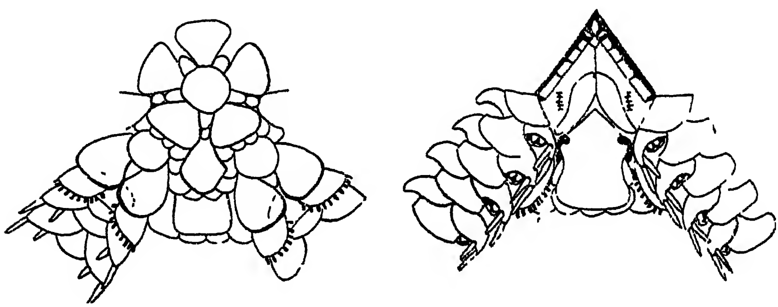

FIG. 18. FIG. 19.

Ophiura kermadecensis.

Fig. 18. Abactinal surface of a portion of disc and base of one ray ($\times$ 10).
Fig. 19. Actinal surface of portion of disc and base of rays ($\times$ 12).

The adradials are exposed, touch one another, and are somewhat pyriform, with a rounded, raised convexity on its distal margin, which, as in the other plates, is pinkish and roughened.

The interbrachial area is occupied by one large quadrate, vertically disposed, plate (fig. 20, *i.b.*), edged on each side by a long narrow plate, and below by 3 rounded plates, which are interposed between it and the oral.

The orals are large, 5-sided, the radial axis being nearly twice the transverse. The two proximal edges are short, and enclose an angle directed towards the mouth. The lateral margins are long and nearly parallel to one another, and the distal or outer edge is convexly rounded. The oral is thrust outwards from the mouth so that its distal margin reaches the edge of the disc, leaving the whole of the 1st and 2nd adambulacrals (*i.e.*, the angle-piece and side mouth-plates) exposed.

There are 4 small quadrate buccal papillae on each angle-piece; a median and a pair of lateral angular papillae; no teeth and no dental papillae.

The arm is cylindrical, tapering, nearly circular in section, inserted in the margin of the disc, with a comb of short spines on each side of the base. This comb consists of 7 spines, of which the lowest is the smallest; they are conical and sharply pointed. The inner series consists of 5 spines.

Put generally, the under arm-plates are small, subpentagonal, with the proximal margin produced into an angle, intervening between the two lateral arm-plates.

The 1st under arm-plate is diamond-shaped; the breadth is greater than its length; the sides are slightly excavated for the pedal pore. The 2nd and 3rd are pentagonal, broader than long. The 4th, 5th, and 6th are somewhat pentagonal, but tend towards a triangle, owing to the rounding-off of the sides and angles. The following plates are transversely oval or pentagonal, with a pronounced angle or peak proximally. The plates get smaller and smaller, but do not disappear, at any rate, before the 20th joint, at which the longest arm is broken.

The side arm-plates meet ventrally after the 5th under arm-plate, where they just touch; but beyond this point the line of union increases in extent, so that soon it coincides with the length of the side arm-plate.

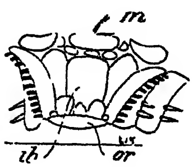

Fig. 20

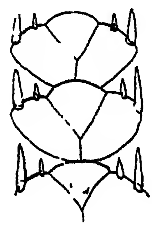

Fig. 21

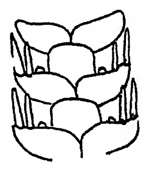

Fig. 22

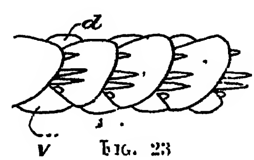

Fig. 23

Ophiura kermadecensis.

Fig. 20. An interbrachial area, seen from the side (× 8). *i.b.*, the large interbrachial plate: *or.* the oral; *m*, marginal.
Fig. 21. Portion of the upper surface of an arm (× 10).
Fig. 22. Portion of the lower surface of an arm (× 10).
Fig. 23 Portion of an arm, seen from the side (× 8). *d*, upper arm-plate; *v*, lower arm-plate.

The upper arm-plates are roughly triangular, with rounded convex distal borders and with the apex directed proximally. They decrease in size till about the 10th, when they disappear, or are so closely and intimately united with the laterals that the suture is indistinguishable.

The side arm-plates carry 3 spines, which spring from the distal border; they are short, cylindro-conical, adpressed to the sides, and with a length about one-third that of the lateral plate. Of these spines, the two lower are rather closer together than the third, which is smaller than they.

There is 1 tentacle-scale throughout the greater portion of the arm; but 2 scales to the first two pairs of pores.

Colour.—In life Mr. Oliver describes the colour thus: "Upper surface of the arms red; the basal portion white, with a red central line; disc pink above; 2 plates [adradials] near the arms are white edged with red; under-surface yellowish." In the dried state they are buff, with pinkish tint on some of the disc-plates.

Locality.—Dredged in 12 fathoms, on gravel bottom, off Meyer Island, and in about 20 fathoms off Denham Bay (5/3/1908). He adds that they are not common.

Remarks.—In the small size and the fewness of the interbrachial plates, with 3 arm-spines, this new species bears some resemblance to *Ophioglypha minuta* Lyman, but in details it differs sufficiently to entitle it to be specially named. *O. minuta* was obtained off the south of Australia.

ECHINOIDEA.

Phyllacanthus dubia Brandt.*

Three dried specimens were forwarded to me, which have the following dimensions:—

Number of [illegible] Plates.	Diameter	Height	Longest Spine.
	Mm.	Mm.	Mm.
6	42	23	44
5	32		36
6	45		48

The spines are nearly uniform in diameter, broadest a little above the base, whence there is a gradual, though slight, decrease towards the tip, and a less decrease towards the neck. Those near the ambitus are more nearly cylindrical. The two upper spines of any vertical row on each interambulacrum are nearly of the same length; the 4th spine is about half this: the others diminish as they approach the peristome. The spines are always worn or corroded.

Locality.—Meyer Island (24/4/1908, 18/5/1908), also Sunday Island (Farquhar, 1906; coll., Haylock). Oliver writes that they "are very rare. The specimens collected are all small, and were found in a rock-crevice near low-water mark. Two or three others were seen in deep water (2 or 3 fathoms)."

Distribution.—New South Wales, Tasmania, Bass Strait, Lord Howe Island, New Caledonia.

Centrostephanus rodgersii A. Agassiz.

Mr. Oliver states that this species is "fairly plentiful among rocks at low water."

The diameter of the corona in these specimens is 80 mm.; height, 35 mm.; longest spine, 55 mm.

The corona when dried is purplish-brown. The colour of the spines when alive is dark purple.

Mr. Farquhar (1906) includes this in our New Zealand fauna, as there is a specimen in the Dominion Museum which is said to have been collected at Wellington; but it is by no means certain that the locality is correct, or that it was found on our coast.

Locality.—Coral Bay, Sunday (Raoul) Island (July, 1908); also Meyer Island.

Distribution.—East and south coasts of Australia, New Caledonia, Lord Howe Island.

* After the MS. had gono to press I had the opportunity while at the Australian Museum, by the kindness of Mr. Coleman, of seeing Döderlein's Ber. ub. d. von Herrn Prof. Semon bei Amboina und Thursday Isl. gesammelten Echinoidea, 1902, wherein the author takes the view that the three species, *P. imperialis* Lamk., *P. dubia* Brandt, *P. parvispina* T.-Wood, are not distinguishablo from one another, and refers the species to the genus *Leiocidaris* Desor., which he regards as including *Cidaris*, *Phyllacanthus*, *Rhabdocidaris*. I have, however, taken a conservative view, as I note that Lyman Clark and other recent writers retain *Phyllacanthus*; while a recent discussion as to the proper names of Cidarids warns me, an outsider, to beware of rushing in where Baxter, Clark, Mortensen, and others have trodden.

Toxocidaris tuberculatus Lamarck.

Strongylocentrotus tuberculatus, Farquhar. Ramsay, &c.

Three individuals were collected. The largest has the following dimensions :—Diameter, 83 mm. : height, 39 mm. : spines, 15 mm. : poriferous zone—above, 6 mm. ; below, 8 mm. : coronal plates, 20 mm.

There are 10 or 11 pairs of pores in an arc ; but below the ambitus, where the zone widens out, the pores are pressed together into a nearly horizontal line of 7 pairs in the widest, decreasing towards the peristome.

Colour.—When alive the " colour of the spines is greenish-brown." When dried they are dark olive-brown, greenish towards the base. with a rosy tinge near the tip. The rosy tip is much more distinct in the spines below the ambitus and around the peristome, perhaps because they have been less bleached. They are here more distinctly green, more truly olive, than above the ambitus; those immediately round the peristome being decidedly green. The test when dried is pale brown.

Locality.—Sunday Island (9/11/1908). Mr. Oliver writes, " This is the most abundant sea-urchin on the Kermadec Islands. Occurs everywhere among the rocks, from low-water mark down. in rock-pools. It was also seen at Macauley Island and French Rock. Continued westerly winds during the winter months shifted the sand from the low flat beach on the north of Sunday Island towards a boulder coast, burying the rocks for a considerable distance along the shore to above the level of low tide. This had the effect of driving thousands of these sea-urchins inshore, where a large proportion perished."

This species has already been recorded from these islands by Farquhar (1906), who received specimens from Mr. Haylock. There is a specimen in the Dominion Museum said to have been collected at Wellington ; and I am informed that at one time there was a specimen in the possession of Mr. Suter which had been collected at Mokohinou, Auckland.

Distribution.—New Zealand, New South Wales, Lord Howe Island, Japan, China.

Remarks.—I have followed Hamann (in Bronn's " Thierreichs ") in placing this species in the genus *Toxocidaris*, which Agassiz erected for those species of *Strongylocentrotus* in which the poriferous zone assumes a " petaloid " form below the ambitus.

It appears that the colour of the spines is very variable. Agassiz (1872, p. 450) says, " The colour of the spines varies from dark violet to black." Ramsay (1885. p. 46, gives them as " uniform olive to olive-brown," and refers for the first time to the flattening of the spines below the ambitus. Agassiz and Clark (1907. p. 122) write that the Japanese specimens " are all (with one exception) large and of a very deep reddish-purple colour."

As Agassiz' account of the spines of *S. erythrogrammus* agrees better with that presented by my specimens—viz., " olive brown, tipped with violet " —I hesitated as to the correctness of my identification, especially as he remarks that the test of *S. tuberculatus* " when dry and denuded is usually greenish, the lower surface whitish." He makes no reference, however, to the colour of the other species ; but from the petaloid widening of the poriferous zone, and the character of the spines and their proportions, I believe that I am correct in placing these specimens under this species.

Tripneustes gratilla L. Agassiz.

T. variegatus, Farquhar, &c.

Of this species I received four dried individuals and two preserved in alcohol. The largest has a diameter of 77 mm., and its height is 35 mm.

Colour.—Oliver notes, " Colour of the spines white to purplish-white." When dried they are white, tipped with pale-reddish tint. The dried test is purplish-red. The ambulacral areas are paler, the interambulacrals darker.

" The short spines distinguish it readily from the other regular echinids of the Kermadecs."

Locality.—Sunday Island (July, 1908): " Large ones were seen in 2-5 fathoms of water in Denham Bay." " Numbers of these sea-urchins were killed by the encroachment of sand on the boulders on which they were living during the winter months, when strong westerly winds prevail." It has been recorded also by Farquhar (1898).

Distribution.—Australia, Lord Howe Island, Fiji, Sandwich Islands, Japan.

Echinometra mathaei Blainville.

E. lucunter, auct.*

Four specimens were sent to me.

Oliver states that the " colour of the spines is white or grey." I find that they are white in the dried specimen, tipped with pale green, with a green axis, as seen on breaking them across. They are superficially ribbed. The smaller spines are wholly green.

Locality.—South Bay, Sunday Island (7/11/1908). Farquhar (1898) has already recorded this species. Oliver says that it is " very rare." They were found " in crevices of rocks and in rock-pools between tide-marks."

Plesianthus testudinarius Gray.

Echinanthus testudinarius, auct.

A single dead test was obtained, dredged in 12 fathoms, on rock and gravel bottom. It had evidently been dead for some time before being collected, for the actinal surface has several patches of polyzoan colonies on it, some flustroid and one tubuloid. The abactinal surface is also corroded, the tubercles being in parts obliterated. The whole surface is quite friable, and easily brushed away when an attempt was made to clean it.

The length of the individual is 115 mm.; the greatest width is at the level of the anterior pair of ambulacra, and is 97 mm.; height, 27 mm.; length of the postero-lateral ambulacrum, 39 mm.; width of the poriferous zone, 3 mm.; interporiferous area, 15 mm.; length of the antero-lateral ambulacrum, 37 mm.; width of poriferous zone, 3 mm.; of interporiferous area, 13·5 mm.

Locality.—Meyer Island, in 12 fathoms (20/5/1908).

Distribution.—Australia, Lord Howe Island, Sandwich Islands, Gulf of California.

* Lyman Clark (1909, p. 520) points out that Loven has already shown that the Indo-Pacific species of *Echinometra* should be termed *E. mathaei*, and that of *Tripneustes T. gratilla*.

Echinoneus cyclostomus Leske.

A single specimen, denuded of spines, was found under stones in rock-pool.

Locality.—Meyer Island (29/2/1908).

Distribution.—Australia, Kingsmill Islands, Zanzibar.

Fibularia australis Desmoulins.

A large number of this little urchin was obtained. Most of them are dried and denuded tests, but there are five in alcohol. They vary in length from 6 mm. to 13 mm.; the largest has a breadth of 11 mm. and a height of 4·5 mm.

Locality.—Sunday Island; dredged in 5 to 10 fathoms. "Dead tests washed up on the beaches in plenty; live ones rarely dredged on sandy bottom, in Denham Bay."

Distribution.—Australia, Sandwich Islands, Kingsmill Islands, Japan.

Brissus carinatus Lamarck.

The material at my disposal consists of one large broken individual and a smaller denuded juvenile test. The larger one measures 72 mm. in length; the other dimensions cannot be given. The postero-lateral ambulacrum is 24 mm. in length, the antero-lateral 21 mm. The subanal fasciole is transversely elongated, heart-shaped.

The colour is uniform purplish-brown.

Mr. Oliver writes, "One live specimen was encountered under a large stone in a rock-pool at Meyer Island, but unfortunately was broken by the crowbar in moving the stone."

The smaller individual, which was washed ashore on Denham Bay beach, is white, having evidently been bleached. There are only a few spines remaining. In outline is recalls Agassiz' figure of *Platybrissus* rather than *Brissus*. It is regularly ovoid, rather narrower posteriorly. The anterior end is rounded when seen in profile, and the posterior end is higher than the anterior, and nearly vertical. There is no keel, which may be due to its youth.

Length, 25 mm.; breadth, 18 mm.; height, 13 mm. The greatest height is at about the level of the posterior ends of the hinder ambulacra: the greatest breadth is nearly at the middle of the animal's length. The lateral margins of the test are nearly parallel. The apical area is near the anterior end, about one-quarter of the total length.

The 4 ambulacra are only slightly sunken; the antero-lateral nearly at right angles to the middle line, slightly curved backwards at first, then outwards and forwards.

The poriferous zone is nearly of the same width throughout. The form of the peripetalous and subanal fascioles is similar to that in the larger specimen. There are some large tubercles at the anterior region of the abactinal surface.

It appears from Bell's study of the species (1879) that it is highly variable; and he points out that Agassiz' figure of *B. carinatus* contradicts his text in regard to the relative lengths of the antero- and postero-lateral ambulacra.

I am not sure that this is the juvenile form of *B. carinatus*, but my literature is insufficient to enable me to trace out its identity.

Distribution.—"*Brissus carinatus* ranges over the entire circumtropical littoral zone" (Bedford, 1900). It has been recorded from Port Jackson, Society Islands, east India, Philippines, Malay, Sandwich Islands, Kingsmill Islands, Japan.

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ART. XX.—*Description of an Undescribed Barnacle of the Genus* Scalpellum *from New Zealand.*

By N. ANNANDALE, D.Sc., F.A.S.B., Superintendent of the Indian Museum, Calcutta.

Communicated by Professor W. B. Benham.

[*Read before the Otago Institute, 5th July, 1910.*]

IN a collection of barnacles from New Zealand recently sent me by Professor W. B. Benham there is a large *Scalpellum*, labelled "*Scalpellum spinosus*," without further data. As this specimen represents a species hitherto undescribed, and as the name has not already been used in the genus, the species may be described as—

Scalpellum (Smilium) spinosum sp. nov.

Capitulum broad, compressed as a whole, but somewhat swollen at the base; the occludent margin vertical, slightly sinuous; the carinal margin feebly curved. Fifteen smooth pinkish valves present, covered with a minutely hairy translucent brownish membrane. *Terga* large, lozenge-shaped, slightly retroverted in the upper third, extending far beyond the carina. *Scuta* broadly triangular, with the bases rounded and tangential to the base of the capitulum; the tips not overlapping the terga. *Carina* short, nearly straight, ridged dorsally but not laterally; the sides of its upper half concave; the base bluntly pointed between the carinal latera.

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

Fig. 1. *Scalpellum spinosum*, half natural size.
Fig. 2. Portion of the peduncle; × 4. (The bands of blunt calcareous spines alternate with bare areas, which are here shaded.)
Fig. 3. Mandible; × 15.
Fig. 4. First and second maxillae; × 15.

Upper latera narrowly triangular, the scutal and lower margins being curved and much longer than the carinal; the scutal angle pointing towards the lateral angle of the scuta. *Rostrum*, *latera of the basal whorl*, and *subcarina* prominent, pointed, spinelike.

Peduncle stout, barely longer than the capitulum, surrounded by numerous sinuous or angulate furrows that separate ridges in which the very numerous peduncular plates are imbedded, these in the form of minute blunted calcareous spines.

Limbs, &c.—*Cirri* colourless, rather short and by no means strongly curved, with a luxuriant fringe on the anterior and well-developed bunches of hairs on the posterior margin. The two rami of the first cirrus subequal, slender, pointed; the first cirrus not widely separated from the second. *Anal appendages* with one joint, which bears a tuft of short hairs at the tip and does not reach the end of the first joint of the protopodite of the sixth cirri. *Penis* rather short, stout at the base, contorted.

Mouth Parts.—*Labrum* slightly bullate, not much produced. *Mandible* with six main teeth in addition to the inner angle; the outermost tooth slightly larger than the second, which is much smaller than the others; the third, fourth, fifth, and sixth subequal; small subsidiary teeth also present between the first and the second and at the outer base of the sixth; the inner angle blunt (perhaps sometimes bifid), bearing several short bristles. *Maxilla* with the free edge straight, bearing a row of bristles of different sizes that decrease gradually from without inwards; inner angle rounded. *Second maxilla* broad, with the free edge slightly sinuous, bearing a fringe of long hairs.

Length of capitulum, 40 mm.; breadth of capitulum at base, 25 mm.

Scalpellum spinosum closely resembles my *S. kampeni*, which occurs off the east coast of Sumatra, at Singapore, and in the Gulf of Siam. From this species it differs not only in its greater bulk, but also as regards the structure of its mouth parts and in the much greater profusion, more regular arrangement, and smaller size of its peduncular plates. The scutum is also broader, and the tergum differs in being retroverted. In the only specimen examined there is no dwarf male.

[*Locality.*—Note by Professor Benham.—The specimen forwarded to Dr. A. Annandale was one of a number received by me in 1899 from Mr. Cox, who was then light-keeper at Farewell Spit, Nelson. The same species was obtained off Stewart Island during the cruise of the "Nora Niven."]

ART. XXI.—*Notes on the Saddleback of New Zealand* (Creadion carunculatus).

By W. W. SMITH, F.E.S.

[*Read before the Manawatu Philosophical Society, 17th March, 1910.*]

A YEAR ago Mr. S. Percy Smith, F.R.G.S., ex-Surveyor-General of New Zealand and distinguished Maori scholar and historian, informed me that when surveying in parts of the North Island many years ago he occasionally observed flights of the popokatea, or whiteheads (*Clitonyx albicapilla*), being followed by saddlebacks in their gregarious migrations through the native forests. This peculiar habit of the saddleback, or native starling, in following flights of, and associating with, other species of birds in the forests was first observed and reported by the gold-diggers during the gold-rush in the great forests of the west coast of the South Island, nearly fifty

years ago. The saddlebacks were first observed following flights of yellow-heads, or native canaries (*Clitonyx ocrocephala*)—the South Island congener of the whitehead—when feeding through the forest.

The younger generation of Maoris having never seen flights of popokateas and tataekos followed by saddlebacks passing in succession through the forests, I have since Mr. Percy Smith informed me endeavoured to elicit from the older Maoris any information respecting their comparative numbers, whether of more frequent occurrence in certain seasons, and the class or nature of the forest where the associated troops of birds were generally met with.

The New Zealand forests vary much in the association of species of plants according to the chemical constitution of the soils, situations, and altitudes on which they occur.

My chief object, therefore, in endeavouring to obtain information from the older Maoris has been to ascertain, if possible, whether particular areas of forest were more frequented by the popokateas and saddlebacks (tieke of the Maori), and, if so, to endeavour also to ascertain the cause. The prehistoric Maori was an accurate observer of natural causes, particularly those affecting his own food-supplies. Replying to my inquiries, Tutu Hihi, a Native of Parihaka, informed me that he had heard his old father speak of the difficulty of procuring kakas, tuis, and kukus (pigeons) in some seasons eighty to ninety years ago, owing to the partial or total failure of their natural foods extending over large areas of forest, and that in such seasons they—the people of his tribe—had to make long excursions to certain more fruitful areas of forest to procure these birds for preserving for winter use. Excepting in the Urewera country, where the old Native methods of bird snaring and trapping are still practised, the old experienced Native bird snarers and trappers of other tribes now living near or within the areas of European or pakeha settlements have all passed away, which, indeed, makes it almost impossible to obtain reliable information on the habits of a species of bird that has become so rapidly extinct since their time and day.

Whilst engaged compiling these notes I wrote to Mr. Percy Smith, inquiring if there were any localities or particular class of forest where the associated birds frequented more than others in the North Island. Having had exceptional opportunities of observing the native birds in the bush in almost every part of the North Island for nearly sixty years, Mr. Smith's reply, here given, should prove of much interest and value: "In the early days here in Taranaki—that is, from fifty to sixty years ago—when I was constantly in the untouched forests then lying behind New Plymouth, often for months at a time, the bird-life was a very prominent feature, and the popokatea one of the commonest birds of all. They used to frequent all the patches of forest in the gullies about the town, also of which at that time there were many. The birds were never seen singly, but always in flocks of about thirty to forty, hopping about from branch to branch, with their little musical twitter. They were invariably accompanied by a pair of saddlebacks, or tieki (or tiaki), who seemed to act as guardians of the flock, giving the alarm, when any one approached, with their sharp notes. The word *tiaki* in Maori means "a guardian," and this, no doubt, was the origin of the name. I spent several years at Kaipara, north of Auckland, in 1859–64, and in the forests there the popokatea was noticed quite as numerous as in Taranaki, always with the accompanying tieki. The last I saw of the popokatea was two years ago, when a flock of about half a

dozen, accompanied by two fantails, passed through the native bush in my garden. I was surprised and pleased to see them, for I had not noticed them for many years previously. I have seen them all over the North Island, but never of late years. Alas ! I fear we may quote the old Maori proverb in reference to them: *Kua ngaro i te ngaro o te moa* (They are lost, like the disappearance of the moa)."

It will be noted that Mr. Percy Smith explains the presence of the saddleback with the whiteheads as guardians to the flock. When closely observing the saddlebacks following the large troop of yellowheads in the Westland forest twenty-two years ago I noted that the former fed eagerly in the trail of the latter in passing slowly on their course. When afterwards describing their associated movements* I raised the theory that the chief object of the tieke in following the yellowheads through the bush was to feed on the larger insects which the latter disturbed and rejected. Apart from the economic importance or otherwise of the remarkable association of these two species, it was to me a magnificent and charming pageant of birds. The last large flight of tataekos, or yellowheads, I observed occurred in March, 1905, in the native beech forest at Sylvan Lake, on the Dart River, flowing into Lake Wakatipu, in Central Otago. Though beautiful their plumage and musical their concerted ringing notes, their charming associates of former days—the tiekes—were absent.

The disappearance or migratory movements from certain districts of some species of native birds, and their return to those districts after years of absence, is due to the fluctuations of supply of their natural and necessary food. The three last mild and fruitful seasons of the native flora have been and are highly favourable to the well-being of the native birds. Many species have bred successfully and multiplied in the larger forest-areas in Taranaki. A continuance of such seasons, which are almost invariably followed by others less fruitful or impoverished, is, no doubt, the cause of the migratory changes of the native birds from districts far apart from each other.

But apart from these phases of the saddleback's history, it is of great interest to note that, notwithstanding the long lapse of time since the separation of the North and South Islands, during the Pliocene period, the method or habit of the saddleback in following the yellowheads in the South Island forests should likewise continue with its white-headed congener in those of the North Island. Though these two forms are now given specific rank, it is probable that the yellowhead has evolved its slightly larger form and yellow coloration in a greater degree in the South Island than the whitehead has developed its typical white coloration in the North Island. That both species have been evolved from the same form or stock having much plainer colours there could be no doubt. But, whilst these two beautiful species of native birds have evolved their divergent typical coloration, the saddleback has apparently undergone no material change in its form and typical colours in either Island during their long separation.

In the supplementary edition of the "History of the Birds of New Zealand" Sir Walter Buller states that the saddleback is now extinct in the North Island. For several years the like was also said of the whitehead. When travelling over nearly the whole of the North Island a few years ago I made numerous inquiries from the Natives wherever I went

* "Birds of Lake Brunner District" (Trans. N.Z. Inst., vol. 21, p. 205, 1889).

respecting the native birds, and ascertained that the whitehead was numerous on the forest-clad ranges whence rise the tributaries of the Motu River, flowing into the Bay of Plenty. During the last two years I have also learned of its occurrence in several other localities, which should remain tapued against avaricious and merciless collectors. In former years the Maoris were great lovers of tamed and caged birds, but only once, after numerous inquiries, have I been able to learn of a caged saddleback having been kept in a Native kainga or village. The older Maoris of the present time also assert that the tieke, or saddleback, was a very difficult bird to snare.

The rapid extinction of this beautiful species of native starling is to me more remarkable than those extinct and expiring species belonging to the New Zealand avifauna. Being strictly a forest-dwelling bird, subsisting on a variety of larvae and insects occurring only in the forest, it was apparently naturally unfitted to change its habits to search for and subsist on other varieties of larvae and insects procurable in the open country. Since improved methods of tillage were introduced by the Taranaki settlers, as in other provinces, several species of native cockchafer beetles (*Odontria*) have increased, as elsewhere in New Zealand, at an unprecedented rate. As the larvae increase in size, and the grass they attack withers, they attract flights of the introduced English starling and the Indian or Eastern minah (*Acridotheres tristis*). With the abundance of larval food on the rich grass lands in the extensive dairying country of Taranaki the starling has increased in such vast numbers as to materially affect the numbers and well-being of the minah. The starlings repair every evening, in flights of several thousands in each, to Moturoa Island, a rugged precipitous rock in the sea nearly a mile from the shore, situated about two miles south of New Plymouth.

In the South Island the starlings roost during the night on *Eucalyptus*, or Australian gum-trees, and in fissures of limestone rocks in many districts. I observe that the minahs prefer to remain closer to the great forest belt or national forest reserve, an area of native forest six miles broad extending all around the base of the extinct volcanic cone of Mount Egmont, in Taranaki. Thus we note that, whilst these introduced species flourish on the abundant and excellent food procurable in the open country, the native tieke, or saddleback, seems to be naturally unfitted to do so, with the inevitable result that the beautiful species has become or is rapidly becoming extinct.

As with other vanished and vanishing species of New Zealand's unique native birds, so with the tieke. All we can possibly do is to faithfully record all facts relating to their habits which have been and are procurable in our tie.

Art. XXII.—*Some Hitherto-unrecorded Plant-habitats* (VI).

By L. Cockayne, Ph.D., F.L.S.

[*Read before the Philosophical Institute of Canterbury, 7th December, 1910.*]

A number of the following records are from Westland, the flora of which district is probably less known than that of any other part of the New Zealand biological region. A number of quite common species are noted from Mount Greenland, as it seems well to give some idea of the florula of a comparatively low mountain (904 m.) situated only a few miles from the coast. It is clad with dense forest, except near the flattish summit, where there is a small patch of grass land and scattered shrubs.

To Messrs. Johannes C. Andersen, H. Hamilton, D. L. Poppelwell, W. Willcox, and W. Wilson I tender my hearty thanks for many specimens, some of which are recorded below.

Abrotanella linearis Bergg.

South Island: Westland—Mount Greenland, near summit, in boggy ground. L. C.

Apium prostratum Labill.

South Island: Nelson—Near Westport, in salt meadow. L. C.

Ascarina lucida Hook. f.

South Island. Westland—An extremely common member of the lowland taxad forest of northern and central Westland, ascending probably to about 180 m. L. C.

Carmichaelia grandiflora Hook. f.

South Island. Westland—Common on lowland river-beds, and attaining a great size. L. C.

Carpha alpina R. Br.

South Island: Westland—Mount Greenland, in boggy ground near the summit. L. C.

Celmisia Armstrongii Petrie.

South Island: Westland—Mount Willberg, subalpine. P. Hende!

Celmisia coriacea (Forst. f.) Hook. f.

South Island: Westland—Styx Saddle, at 760 m. and upwards. H. Hamilton.

Celmisia incana Hook. f. var. **petiolata** T. Kirk.

South Island: Westland—Mount Greenland, near summit. L. C.

I think it would be better to unite this widely spread form with *C. discolor*, or to constitute it a species, restricting *C. incana* to the series of forms with lax, soft, snow-white tomentum on both sides of the leaf.

Celmisia longifolia Cass. var. **alpina** T. Kirk.

South Island: Westland—Mount Greenland, in boggy ground near the summit. L. C.

Coprosma rigida Cheesem.

South Island: (1) Nelson—Common in swampy forest in vicinity of Westport; L. C. (2) Westland—Common in similar situations; L. C.

Coprosma Banksii Petrie.

South Island: Westland—Mount Greenland, in subalpine scrub. L. C.

Coprosma Colensoi Hook. f.

South Island: Westland—Mount Greenland, in subalpine scrub. L. C.

Coprosma cuneata Hook. f.

South Island: Westland—Mount Greenland, in subalpine scrub. L. C.

Coprosma rugosa Cheesem.

South Island: Westland—Common on lowland river-bed. L. C.

Cordyline indivisa (Forst. f.) Steud.

South Island: Westland—Mount Greenland. L. C.
This is probably the so-called nikau-palm of the district.

Cyathea Cunninghamii Hook. f.

South Island: Westland—Hende's Ferry, in shady gullies at base of the Willberg Range. L. C.

Cyathea medullaris (Forst. f.) Sw.

South Island: Westland—Neighbourhood of Hende's Ferry. P. Hende!
According to the late Mr. J. G. Roberts, it occurred only on sea-coast slopes from Pakorari to Teremakau, and from Paringa to the Cascade River ("Forestry in New Zealand," p. 57, 1909).

Dacrydium Bidwillii Hook. f.

South Island: Nelson—Mount Rochfort. L. C.

Dacrydium biforme (Hook.) Pilger.

South Island: Westland—Mount Greenland, in the subalpine scrub. L. C.

Dacrydium laxifolium Hook. f.

South Island: Nelson—Mount Rochfort. L. C.

Discaria toumatou Raoul.

South Island: Westland—Wataroa. W. Wilson.
Mr. Wilson, District Surveyor, informs me that he has observed this species in only the one locality in Westland, and that he is of opinion it has been introduced from Canterbury by travelling stock. Roberts (*loc. cit.*, p. 57) states that the shrub has been found in only one or two places in Westland, and always as an isolated plant, but never in mass.

Dodonaea viscosa Jacq.

South Island: Westland—North of Greymouth, on gravelly beach. L. C.

Donatia novae-zelandiae Hook. f.

South Island: Westland—Mount Greenland, in boggy ground near summit. L. C.

Dracophyllum Traversii Hook. f.

South Island: Westland—Mount Greenland, in subalpine scrub. L. C.

Although not many actual records are available, this tree appears to be very common in the subalpine belt of Westland, while at the Franz Josef Glacier it descends to less than 300 m.

Drosera arcturi Hook.

South Island: Westland—Mount Greenland, in boggy ground near the summit. L. C.

Drosera spathulata Labill.

South Island: Westland—Mount Greenland, in bog near the summit. L. C.

Elaeocarpus Hookerianus Raoul.

South Island: Westland—From lowland to subalpine belts, where it is common on Mount Greenland. L. C.

Evidently not a common tree in Westland, as it is not mentioned in Roberts's paper.

Exocarpus Bidwillii Hook. f.

South Island: Canterbury—Puketeraki Mountains, at about 600 m. L. C.

Freycinetia Banksii A. Cunn.

South Island: Westland—Common as liane of the lowland forest, and as creeping plant on rocks near high water. L. C.

Gahnia procera Forst.

South Island: Westland—Mount Greenland, in upper forest and subalpine scrub. L. C.

Gaimardia ciliata Hook. f.

South Island: Westland—Mount Greenland, in bog near summit. L. C.

Gaultheria perplexa T. Kirk.

South Island: (1) Nelson—Reefton; L. C. (2) Otago—Dunedin, open ground on Signal Hill; L. C.

Griselinia lucida Forst. f.

South Island: Westland—Epiphytic on various trees in the low forest close to sea between Greymouth and Kumara. L. C.

Hoheria sexstylosa Colenso.

South Island: Nelson—Vicinity of Westport. L. C.

This is probably *Hoheria populnea* A. Cunn. var. *angustifolia* Hook. f. of Townson's list of Westport plants (Trans. N.Z. Inst., vol. 39, p. 406, 1907). It extends southwards to Greymouth, but I have not noted it south of the Teremakau Valley in Westland.

Lycopodium varium R. Br.

South Island: Nelson—Charleston, near sea. L. C.

Mariscus ustulatus (A. Rich.) C. B. Clarke.

South Island: Westland—Gravelly beach between Greymouth and Kumara. L. C.

Melicytus lanceolatus Hook. f.

South Island: Canterbury—Mount Peel, in forest. L. C.

Metrosideros Colensoi Hook. f.

South Island: Nelson—Between Westport and Charleston. L. C.

Metrosideros florida (Forst. f.) Sm.

South Island: Westland—Lowland forest; common as far south as the Waiho River, and perhaps further. L. C.

Myosotis Goyeni Petrie.

South Island: Otago—Queenstown, on rocks near the cemetery. W. Willcox!

Nothofagus apiculata (Colenso) Cockayne comb. nov. = *Fagus apiculata* Col. in Trans. N.Z. Inst., vol. 16, p. 335, 1884.

South Island: Marlborough—Mount Fyffe, Seaward Kaikoura Mountains, 150 m. altitude, growing in company with *N. fusca.* W. M. Goodall!

The specimens were not in flower, but they correspond to the description in Cheeseman's Flora, except that the leaves generally are less than ¾ in., and the pubescence on the branchlets is very scanty.

Nothofagus Blairii (T. Kirk) Cockayne comb. nov. = *Fagus Blairii* T. Kirk in Trans. N.Z. Inst., vol. 17, p. 297, 1885.

South Island: Marlborough—Mount Fyffe, Seaward Kaikoura Mountains, about 150 m. altitude. W. M. Goodall!

The specimens bore a few damaged male flowers. As far as I could make out, they are in pairs upon a short common peduncle, the perianth is 4-toothed, and the stamens vary from 8 to 14; but the material was insufficient for an accurate description.

Nothofagus cliffortioides (Hook. f.) Oerst.

South Island: Nelson—Charleston, close to sea, where exposed to full force of wind. L. C.

Nothofagus Menziesii (Hook. f.) Oerst.

South Island: Westland—Near River Paringa. W. Wilson!

Nothopanax anomalum (Hook.) Seem.

South Island: Nelson—Buller Gorge and neighbourhood. L. C.

Olearia Colensoi Hook. f.

South Island: Westland—Mount Greenland, in subalpine scrub. L. C.

Olearia ilicifolia Hook. f.

South Island: Westland—Lowland river-beds; common. L. C.

Olearia lacunosa Hook. f.

South Island: Westland—Mount Greenland, in subalpine scrub; not abundant. L. C.

Olearia lineata (T. Kirk) Cockayne sp. nov. = *O. virgata* Hook. f. var. *lineata* T. Kirk in "The Students' Flora of New Zealand," p. 276, 1899.

South Island: Westland—Near River Wanganui. W. Wilson!

Olearia mollis (T. Kirk) Cockayne sp. nov. = *O. ilicifolia* Hook. f. var. *mollis* T. Kirk in "The Students' Flora of New Zealand," p. 269, 1899.

South Island: Westland—Head of Otira Gorge, in the low forest. L. C.

If it be right to separate *O. ilicifolia* and *O. macrodonta* although their inflorescences and heads are virtually identical—and in so doing there is the authority of Hooker, Kirk, and Cheeseman—then the variety *mollis* of *O. ilicifolia* may be equally considered a valid species. The differences between the two plants are sufficiently noted by Cheeseman (Manual, p. 286).

Olearia moschata Hook. f.

South Island: Westland—Balfour, Fox, and Karangarua Rivers, in subalpine scrub. C. E. Douglas!

This is the "incense-plant" of Roberts (*loc. cit.*, p. 58) and of various reports on survey of Westland.

Oreobolus pectinatus Hook. f.

South Island: Nelson—Charleston, near sea. L. C.

Oreobolus strictus Berggr.

South Island: Westland—Mount Greenland, in boggy ground near the summit. L. C.

Ourisia glandulosa Hook. f.

South Island: Otago—Ben Lomond, 1,500 m. altitude. W. Willcox!

Ourisia macrophylla Hook.?

South Island: Nelson—Vicinity of Reefton. L. C.

Pennantia corymbosa Forst.

South Island: Westland—One of the members of the low forest of lowland river-beds. L. C.

The Westland settlers must surely have some local name for this tree, so conspicuous when in bloom; but, at any rate, it is not known by its Maori name, kaikomako (see Roberts, *loc. cit.*, p. 56).

Pimelea longifolia Banks & Sol.

South Island: Westland—Paparoa Range, near the Blackball Mine. W. Wilson!

This extends the recorded range a little further to the south.

Pittosporum divaricatum Cockayne sp. nov. ined.

South Island: Westland—Mount Greenland, in the subalpine scrub. L. C.

This is the common South Island form, which I consider quite distinct from the type which grows in various parts of the Central Botanical Province. I hope to publish a description shortly.

Poa pusilla Berggr.

South Island: Nelson—Charleston, near the sea. L. C.

Pseudopanax lineare (Hook. f.) C. Koch.

South Island: Westland—Mount Greenland, in the subalpine scrub. L. C.

Quintinia acutifolia T. Kirk.

South Island: Westland—From sea-level to 900 m. altitude; a most characteristic forest-tree. L. C.

Rubus parvus Buch.

South Island: Westland—(1) Open ground near the Otira Railway-station; L. C. (2) Styx Saddle; subalpine; H. Hamilton.

Rubus schmidelioides A. Cunn.

South Island: Nelson—Westport district; abundant. L. C.

Rubus schmidelioides A. Cunn. var. **coloratus** T. Kirk.

South Island: Nelson—Westport district. L. C.

Senecio bellidioides Hook. f.

South Island: Otago—Common near Gore, at altitude of 75 m. D. L. Poppelwell!

Cheeseman gives 2,000 ft. as the lowest altitudinal limit (Manual, p. 371).

This is by no means typical, the bristles, which are considered a specific mark, being altogether wanting or extremely few in number.

Senecio elaeagnifolius Hook. f.

South Island: Westland—(1) Mount Greenland, in the subalpine scrub; L. C. (2) Common in scrub of lowland river-beds; L. C.

Triodia exigua T. Kirk.

South Island: Canterbury—Waimakariri River bed, at less than 30 m. altitude. L. C.

Urtica ferox Forst. f.

South Island: Westland—Wataroa. J. G. Roberts.

Veronica tetrasticha Hook. f.

South Island: Canterbury—Mount Burnett, 1,650 m., on rock. Johannes C. Andersen!

ART. XXIII.—*New Species of Plants.*

By T. F. CHEESEMAN, F.L.S., F.Z.S., Curator of the Auckland Museum.

[*Read before the Auckland Institute, 22nd November, 1910.*]

1. **Lepidium tenuicaule** T. Kirk var. **minor** Cheesem. n. var.

Planta pumila, depressa; caulibus brevissimis, 1–2½ cm. longis; foliis numerosibus, omnibus radicalibus.

Hab.—North Island: Titahi Bay, near Wellington; *B. C. Aston!*

A curious little plant, differing from all the specimens of *L. tenuicaule* that I have seen in the much-reduced size, the stems never exceeding an inch in length. The whole plant is also much more thick and fleshy than is usual in the typical state. I have not seen ripe fruit, but the flowers appear to match those of the ordinary form. Mr. Aston is the first to discover the species in the North Island.

2. **Chordospartium** Cheesem. gen. nov.

Arbor vel frutex parva, aphylla; ramis junceis pendulis, squamulis ad nodos minimis. Flores purpurei, in racemos multifloros dispositi. Bracteae et bracteolae parvae. Calycis dentes breves, subaequales vel superiores minores. Vexillum orbiculatum, reflexum, in unguem brevem contractum; alae dolabriforme-falcatae, liberae, vexillo breviores; carina incurva, obtusa, vexillum subaequans. Stamen vexillare liberum, caetera in vaginam connata; antherae uniformes. Ovarium sessile, sericeum, 3–5-ovulatum; stylus incurvus, apice inflexus, intus longitudinaliter barbatus; stigmate minuto terminali. Legumen brevem, turgidum, rhombeo-ovoideum, incurvum, indehiscens. Semen solitarium, estrophiolatum; radicula elongata, biplicata.

Chordospartium Stevensoni Cheesem. species unica.

A leafless shrub or small tree, sometimes attaining a height of 20 ft. or more, with a trunk 6–8 in. in diameter. Branches long, slender, pendulous, terete or subcompressed, grooved; branchlets $\frac{1}{15}$ in. diameter, glabrous, marked with distant nodes, each node with a minute scale. Leaves not seen. Racemes springing from the nodes of the branchlets, single or in fascicles of 2–5, ¾–1½ in. long, very many-flowered; rhachis densely woolly; pedicels very short; bracts and bracteoles minute. Flowers ⅓ in. long, purple, with darker lines on the standard. Calyx densely woolly, cup-shaped, minutely 5-toothed. Standard orbicular, reflexed, narrowed into a very short claw at the base. Wings dolabriform, falcate, obtuse, shorter than the keel. Keel incurved, obtuse, equalling the standard. Upper stamen free; the others connate into a sheath. Ovary sessile, densely silky, linear-oblong, gradually narrowed into the style; ovules 3–5; style long, slender, incurved, longitudinally-bearded on the inner side above; stigma minute, terminal. Pod about ⅕ in. long, more or less silky, short, turgid, ovoid or orbicular-rhomboid, straight in front, rounded at the back. Seed solitary, transversely oblong; radicle long, with a double flexure.

Hab.—South Island: Foothills of the Seaward Kaikoura Mountains, near the mouth of the Clarence River; altitude, 1,500–2,500 ft.; *Mr. George Stevenson!*

A very remarkable plant, in some respects connecting the genera *Corallospartium*, *Carmichaelia*, and *Notospartium*. It agrees with the first in the short turgid subrhomboid 1-seeded pod, and in the grooved branchlets, but differs altogether in habit, in the slender branchlets, and in the markedly different inflorescence. From the section *Huttonella* of *Carmichaelia* it is separated by the same characters. It entirely corresponds with *Notospartium* in habit and inflorescence, and has probably been mistaken for that genus in the absence of fruit, which at once distinguishes the two genera.

Although I consider that the characters of *Chordospartium* fully justify its erection into a separate genus, it must be confessed that the differences between it and *Corallospartium* are not of a very pronounced type. If, however, differences of habit, inflorescence, &c., are not considered sufficient to separate *Corallospartium* and *Chordospartium*, then, by parity of reasoning, similar characters of no greater importance cannot be used to distinguish both these groups from the section *Huttonella* of *Carmichaelia*, and the three genera must merge into one. Some botanists may prefer this course, for it is very much a matter of taste and personal idiosyncrasy whichever view is adopted.

I have to express my obligations to Mr. Stevenson for his kindness in forwarding an ample supply of both flowering and fruiting specimens. Most of these were obtained from a tree growing near his house, which he describes as a beautiful specimen, with a stem bare of branches for about 8 ft., above which "it is a perfect weeping model all round for quite 15 ft." Its girth at about 2 ft. from the ground was 20 in. The flowering season stretches from the middle of November to the end of December, and the fruit is ripe at the beginning of April. I have also to thank Mr. T. Keir, of Rangiora, for placing me in communication with Mr. Stevenson, and for much valuable assistance in obtaining specimens and information. A drawing of the plant, with full analyses, will appear in the forthcoming "Illustrations of the New Zealand Flora."

3. Senecio Turneri Cheesem. sp. nov.

Affinis *S. latifolio* Banks et Soland., sed foliis magnis ovato-cordatis distinctissima.

Caulis robustus, 0·6–1·8 m. altus, inferne lignosus, prostratus vel decumbens, nudus; superne erectus, foliatus; versus apicem ramosus. Folia alterna, magna; petioli 15–30 cm. longa, basi longe vaginantes; lamina 10–18 cm. longa, 7–15 cm. diam., cordata vel rotundata-cordata, acuta, membranacea; venis reticulatis; marginibus sinuatis et spinuloso-serratis. Folia caulina minora, petiolis brevioribus, auriculis magnis. Bracteae numerosae, lanceolatae. Corymbi laxi, ramosi; ramis gracilibus. Capitula numerosa, 2–3 cm. diam.; involucri squamae 1-seriales, lineares vel lanceolatae, glabrae vel parce pubescentes. Achenia matura non visa. Pappus mollis, copiosus, albus.

Hab.—North Island: On the faces of wet cliffs by the Upper Wanganui River, both above and below the junction of the Mangaio Stream, *E. Phillips Turner!*

A stout glabrous herb 2–6 ft. high. Stem as thick as the finger, woody, prostrate or decumbent and usually naked at the base, leafy above, sparingly branched at the top only. Leaves alternate, large, spreading, bright green; petiole 6–12 in. long, winged at the base and broadly amplexicaul, smooth

and terete above; blade 4–7 in. long by 3–6 in. across, cordate to orbicular-cordate, deeply lobed at the base, acute at the tip, thin and membranous, veins reticulate, margins sinuate and finely spinuloso-serrate. Cauline leaves smaller, on shorter petioles, with large leafy auricles and smaller narrower blades, gradually passing into lanceolate or linear entire bracts. Corymbs large and broad, much branched, branches slender. Heads very numerous, $\frac{3}{4}$–$1\frac{1}{4}$ in. diameter, bright yellow; involucral bracts in a single series, linear or oblong-linear, acute, glabrous or finely pubescent. Ray-florets 10–15; ligule narrow, spreading; disc-florets 25–35. Ripe achenes not seen. Pappus soft, copious, white.

One of the most distinct species added to the New Zealand flora of late years. Although allied to *S. latifolius*, it differs widely in habit, in the large cordate leaves, which are never lobulate or pinnatifid, but have their margins finely spinulose-serrate, in the long terete petioles, and in the larger flower-heads. I have much pleasure in dedicating it to its zealous discoverer, who has done excellent botanical work in the interior of the North Island of late years.

Mr. Turner remarks, "As far as at present noticed, the plant is restricted to the mouth of the Mangaio Gorge and the steep papa cliffs of the Wanganui River above and near the junction, but I have found only one place at which it can be conveniently reached. It is associated with *Ourisia macrophylla*, *Senecio latifolius*, *Elatostemma rugosum*, and *Lomaria capensis*, and grows only where the cliffs are wet and shaded. From a little distance the large bright-green leaves give the plant somewhat the appearance of the arum lily."

4. **Thelymitra Matthewsii** Cheesem. sp. nov.

T. variegata Lindl. affinis, sed caule multo breviore, floribus singularibus, gynostemio non cristato.

Caulis gracilis, flexuosus, 9–14 cm. longus. Folium solitarium, 3–6 cm. longum, spiraliter contortum, lineare, basi ampliato. Bracteae 2. Flos solitarius, ratione plantae magnus, 1–2 cm. diametro. Perianthium sub regulare, patens. Sepala et petala similia, lanceolata vel ovato-lanceolata, acuta vel acuminata. Gynostemium breve, bialatum, aliis magnis, crassis, clavatis, obtusis, apice non fimbriatis aut lobatis.

Hab.—North Island: Mangonui County, low hills between Lake Tongonge and the coast; *R. H. Matthews!*

Stem slender, wiry, flexuose, 4–6 in. high. Leaf solitary, sheathing the stem at the base, the sheath finely and closely puberulous; lamina $1\frac{1}{2}$–$2\frac{1}{2}$ in. long, much expanded at the base, and then suddenly narrowed into a linear blade, which is usually spirally twisted so as to coil round the stem; margins involute. Bracts 2, the lower one below the middle of the stem, the upper almost close to the flower, both broad and sheathing. Flower solitary, large for the size of the plant, $\frac{1}{2}$–$\frac{3}{4}$ in. diameter. Perianth-segments alike, lanceolate or oblong-lanceolate, acute or shortly acuminate, dark purplish-blue with darker longitudinal veins. Column much shorter than the perianth-segments, not produced at the back behind the anther, but furnished with two large lateral lobes which equal the anther in height, and which are oblong or oblong-falcate, obtuse, somewhat flattened but thick and fleshy, not lobed nor furnished with cilia. Occasionally there are evidences of a slight crest connecting the lateral lobes at the base. Anther very large, oblong, obtuse. Base of the column purplish; lateral lobes and anther bright yellow.

A charming little plant, worthily dedicated to its discoverer, who has added more to our knowledge of the New Zealand orchids than any other observer of late years. It is closely allied to the Western Australian *T. variegata* Lindl., principally differing in the much smaller size, in the solitary flowers, and in the column-wing scarcely crested on the back behind the anther. Mr. Matthews informs me that the remarkable spiral twist or coil in the leaves is constant in all the specimens he has seen. This peculiarity is also more or less observable in *T. variegata.*

Art. XXIV.—*Contributions to a Fuller Knowledge of the Flora of New Zealand: No. 4.*

By T. F. Cheeseman, F.L.S., F.Z.S., Curator of the Auckland Museum.

[*Read before the Auckland Institute, 22nd November, 1910.*]

I. Ranunculaceae.

Clematis parviflora A. Cunn.

Common among scrub on the outskirts of the forest, Little Barrier Island; *Miss Shakespear! T. F. C.*

Clematis marata Armstr.

Vicinity of Wanganui; *A. Allison!*

Ranunculus geraniifolius Hook. f.

Western slopes of Tongariro; altitude, 5,500 ft.; rare; *T. F. C.* In peaty soil on the summit of Mount Hauhungatahi; altitude, 4,500 ft.; *Rev. F. R. Spencer!*

Caltha novae-zealandiae Hook. f.

I am indebted to *Mr. F. G. Gibbs* for specimens of this in which the leaves are almost devoid of the reflexed lobules so conspicuous in the ordinary state of the species.

III. Cruciferae.

Cardamine bilobata T. Kirk.

Sheltered places in the Hooker Valley, Mount Cook district; altitude, 3,000 ft.; rare; *T. F. C.*

Cardamine and Nasturtium.

In the Manual I have alluded to the fact that at least three of the New Zealand species previously referred to *Cardamine* differ from that genus in the seeds being 2-seriate, the species in question being *C. fastigiata, C. latesiliqua,* and *C. Enysii.* Schulz, in his monograph of *Cardamine* (Engl. Jahr., 32) excludes all three from the genus, but does not make any other disposition of them. He also removes *C. stylosa,* in this instance

referring it to *Nasturtium*. Whether the above-mentioned three species should also be transferred to *Nasturtium* is not easy to decide, as there are differences in habit and in the shape and structure of the pod which appear to be of considerable importance. Possibly they should form a separate genus, in which case the Australian *C. radicata* should be associated with them. A step of that kind, however, involves an examination of the characters of most of the genera constituting the tribe *Arabidae*, and is preferably left in the hands of some systematist who is able to consult the great herbaria and libraries of Europe. In the meantime it appears best to place the species with *C. stylosa* in *Nasturtium*. They will then stand as under :—

1. *Nasturtium stylosum* O. E. Schulz in Engl. Jahr., 32 (1903), p. 596; *Cardamine stylosa* D. C.
2. *Nasturtium fastigiatum* Cheesem.; *Cardamine fastigiata* Hook. f., Handb. N.Z. Fl., p. 13.
3. *Nasturtium latesiliqua* Cheesem.: *Cardamine latesiliqua* Cheesem. in Trans. N.Z. Inst., vol. 15 (1883), p. 298.
4. *Nasturtium Enysii* Cheesem.; *Cardamine Enysii* Cheesem. ex T. Kirk, Students' Fl., p. 28.

Lepidium tenuicaule T. Kirk.

A dwarf form of this plant, which I have elsewhere described under the name of variety *minor*, has been collected by *Mr. B. C. Aston* at Titahi Bay, near Wellington. This is the first record for the species in the North Island.

IV. VIOLACEAE.

Melicytus micranthus Hook. f.

In the Manual I have given the Bay of Islands as the northern limit of this species; but both *Mr. Carse* and *Mr. R. H. Matthews* inform me that it occurs in several localities near Kaitaia, in Mangonui County.

V. PITTOSPORACEAE.

Pittosporum tenuifolium Banks & Soland.

Variegated forms of this species and of *P. eugenioides* A. Cunn. are now frequently seen in cultivation.

VII. PORTULACEAE.

Hectorella caespitosa Hook. f.

Mount Ollivier, Mount Wakefield, Mount Kinsey, and other peaks in the Mount Cook district, ascending to 6,500 ft.; *T. F. C.*

X. MALVACEAE.

Hoheria populnea A. Cunn. var. **angustifolia** Hook. f.

Not uncommon on river-flats in the Turakina Valley: *F. R. Field!*

XXII. LEGUMINOSAE.

Corallospartium crassicaule Armstr.

Mr. A. W. Roberts, of Ranfurly, Otago, sends me a yellow-flowered variety. The ordinary colour, to which I have never previously seen any exception, is a pale cream. Both *Mr. Roberts*, and *Mr. McIntyre*, of

Dunedin assure me that the pod is always indehiscent, the face of the valves slowly decaying after the fall of the pod. I find that it is occasionally 2-seeded.

XXIV. Saxifragaceae.

Donatia novae-zealandiae Hook. f.

Donatia has been transferred to the *Stylidiaceae* by Mildbraed in his recently published monograph of the family (Engler's "Pflanzenreich," heft 35). In this he has followed the late Baron Mueller, who suggested the change as far back as 1879. No doubt the genus agrees with the *Stylidiaceae* in the stamens being placed in the centre of an epigynous disc, in the extrorse anthers, and in the placentation; and the habit is very similar to that of *Phyllachne*. But it differs markedly in the free petals, and in the stamens not being united with the style into a "column." We may expect that systematists will not readily agree as to the position of the genus.

XXVII. Haloragaceae.

Myriophyllum pedunculatum Hook. f.

In great abundance by the margins of shallow ponds among the sand-dunes on the west coast near Helensville, Kaipara. I suppose that it is referable to the form which Schindler has distinguished as a separate species under the name of *M. Votschii* ("Pflanzenreich," heft 23, p. 85). but the differences appear to me to be very trivial.

XXVIII. Myrtaceae.

Metrosideros robusta A. Cunn.

Not uncommon at West Wanganui, to the south of Cape Farewell: *H. J. Matthews!*

Metrosideros scandens Soland.

Dry ridges in lowland forests near Greymouth, Westland; not uncommon; *P. G. Morgan!* The most southern locality from whence I have seen specimens.

XXXIII. Umbelliferae.

Aciphylla Dieffenbachii T. Kirk.

I have to thank *Mr. F. A. D. Cox*, the veteran botanical explorer of the Chatham Islands, for excellent specimens in fruit and a few in flower of this remarkable plant. It is now exceedingly rare, having been destroyed by sheep in most localities to which they have access, but it still lingers on the faces of a few rocky cliffs near Te Tuku, on Mr. Bligh's sheep-station. In this locality it was also seen by *Captain Dorrien-Smith* during his recent visit to the Chatham Islands.

In the "Students' Flora" Mr. T. Kirk hinted at the probability of the plant constituting a separate genus, and I expressed the same opinion in the Manual. Not only does it differ from *Aciphylla* in the flaccid habit and large oblong much-compressed fruit, but a section of the fruit shows that the vittae are of enormous size, quite unlike anything to be seen in *Ligusticum*, *Aciphylla*, or *Angelica*. In the forthcoming "Illustrations of the New Zealand Flora" it will accordingly be figured as the type of a new genus, to which the name *Coxella* will be applied. I have much

pleasure in associating the plant with the name of Mr. Cox, who for very many years has supplied New Zealand botanists with copious suites of the endemic plants of the Chatham Islands, often at considerable trouble to himself.

Angelica Gingidium Hook. f.

Limestone rocks by the Rakaunui River, Kawhia. *E. Phillips Turner!* Not previously recorded from any station to the north of the Taupo country.

XXXVII. RUBIACEAE.

Nertera Cunninghamii Hook. f.

Wangapeka Valley, Nelson, *F. G. Gibbs!*

XXXVIII. COMPOSITAE.

Brachycome Thomsoni T. Kirk **var. membranifolia.**

Cobb Valley, north-west Nelson; *F. G. Gibbs!* A slight northwards extension of the range of this variable plant.

Olearia virgata Hook. f.

Attains its northern limit in the Ohinemuri Valley, Thames, between Karangahake and Waitekauri, *T. F. C.*

Cotula pectinata Hook. f.

Mount Ollivier and other mountains in the Mount Cook district, 5,000–6,500 ft.; *T. F. C.*

XLI. CAMPANULACEAE.

Pratia perpusilla Hook. f.

Outlet of the Waikato River, Lake Taupo: *T. F. C.* Low grounds in the Thames Valley, near Te Aroha; *P. H. Allen!*

XLV. MYRSINACEAE.

Myrsine divaricata A. Cunn.

Mr. F. G. Gibbs forwards specimens of this species, from some locality in the Nelson Provincial District, in which the leaves are coarsely and irregularly toothed or almost lobed.

XLVI. SAPOTACEAE.

Sideroxylon costatum F. Muell.

This appears to be a very local plant on the west coast of the North Island. So far as my own observations go, it is found in only two localities —the first in the vicinity of Maunganui Bluff (between Hokianga and Kaipara); the second on the coast-line north of the Manukau Harbour, when it occurs in scattered localities along a stretch of eight or ten miles of coastal cliffs. On the eastern side of the Island it is much more generally distributed, although nowhere abundant.

The late Baron Mueller separated the New Zealand plant from that found in Norfolk Island, giving it the name of *Achras novo-zealandica* (Fragm. Phyt. Austral., vol. 9, p. 72). In this he was probably right, as has been pointed out by Mr. Hemsley (" Kew Bulletin," 1908, p. 459). Under

this view the name to be adopted for our plant will be *Sideroxylon novo-zelandicum* Hemsl.

XLVII. Oleaceae.

Olea montana Hook. f.

Maungataniwha Ranges and vicinity of Fairburn (Mangonui County); *H. Carse*: the most northern locality yet recorded. Vicinity of Cape Brett Lighthouse: *R. H. Shakespear!*

LI. Boraginaceae.

Myosotis angustata Cheesem.

Mount Lockett, north-west Nelson; *F. G. Gibbs!* Moraines in the Hooker Valley, Mount Cook district: altitude, 4,000 ft., *T. F. C.*

LIV. Scrophulariaceae.

Calceolaria repens Hook. f.

Makatote Gorge and other ravines on the volcanic plateau of the North Island, along the course of the Main Trunk Railway; *T. F. C.*

Veronica gracillima Cheesem.

Sea-cliffs a little to the north of Gisborne; *W. Townson!* This is the first record of the occurrence of this species in the North Island.

Veronica rupicola Cheesem.

Hell's Gates, near Kaikoura: *H. J. Matthews!* Most of the specimens have simple racemes, thus departing from the typical state of the species, in which the racemes are nearly always trichotomous.

Ourisia sessilifolia Hook. f.

An abundant plant on most of the mountains in the Mount Cook district, forming large patches on the sides of moist sheltered hollows, 4,500–6,500 ft. altitude; *T. F. C.*

LVIII. Verbenaceae.

Teucridium parvifolium Hook. f.

On the outskirts of patches of swampy forest by the Thames River, Te Aroha: *T. F. C.* I mention this locality because drainage operations and the destruction of the forest is fast destroying the plant.

LXXII. Loranthaceae.

Korthalsella salicornioides Van Tiegh.

Although this stretches through almost the whole length of both the North and South Islands, it is everywhere local and rarely occurs in any great quantity. The following are the habitats known to me:—

I. North Island: Vicinity of Kaitaia (Mangonui County); *R. H. Matthews!* Kerikeri Falls, Bay of Islands (the locality where it was first discovered); *R. Cunningham, W. Colenso! Hooker*, and many others. Open *Leptospermum* country between the Kerikeri River and Waitangi; *T. F. C.* Whangarei; *T. Kirk.* Little Barrier Island: *Miss Shakespear! T. F. C.* Judge's Bay, near Auckland; and by the Manukau Harbour, in the vicinity

of the South Whau Blockhouse; now almost extinct in both localities; *T. F. C.* Near Tararu, Thames; *W. Hammond!* Near Tairua, *J. Adams!* Rotorua; *T. Kirk! T. F. C.* Taupo Plains; *T. Kirk.* Humangaroa River, near Martinborough; *Rev. F. R. Spencer!* Waikanae; *Dr. Cockayne.*

II. South Island: Vicinity of Collingwood; *J. Dall!* Banks Peninsula: *J. B. Armstrong.* Vicinity of Dunedin, at Anderson's Bay and Pelichet Bay; *D. Petrie!*

LXXIV. BALANOPHORACEAE.

Dactylanthus Taylori Hook. f.

Pipiriki, on the Upper Wanganui River; *E. Phillips Turner,* who informs me that he noticed several specimens growing on *Geniostoma*, for which as a host I am not aware of any previous record. Kaitoke, near Wellington; *J. S. Tennant* and *B. C. Aston!*, parasitic on *Pittosporum eugenioides.*

LXXVI. URTICACEAE.

Urtica ferox Forst.

Abundant on rich alluvial soils by the Marikopa River, Kawhia County, and attaining a large size; *E. Phillips Turner.* The most northerly station yet recorded on the west side of the North Island.

LXXVII. CUPULIFERAE.

Fagus fusca Hook. f.

This is the only species of the genus that occurs to the north of the Auckland isthmus, and its distribution therein is so local that it appears advisable to quote the known habitats, more especially as it is in danger of extinction in several of them.

Near Kaitaia, Mangonui County; *W. Colenso, R. H. Matthews, H. Carse.* I am informed that only a few trees now remain in this locality. Whangarei; once abundant in several stations, but fast being reduced in numbers; *W. Colenso, R. Mair, T. F. C.* Little Omaha; *T. Kirk, T. F. C.* Little Barrier Island; abundant; *T. F. C.* Kawau Island; *J. Buchanan, T. Kirk.* Waiheke Island; *T. Kirk, T. F. C.*; once comparatively plentiful, now very scarce. Near Chelsea (Auckland Harbour); a few trees only; *T. F. C.*

LXXVIII. CONIFERAE.

Podocarpus dacrydioides A. Rich.

Mr. E. Phillips Turner, Inspector of Scenic Reserves, informs me that he has recently measured a kahikatea at Kakahi (a little to the south of Taumarunui) that proved to be 195 ft. in height. So far as I am aware, this is the tallest tree yet measured in the Dominion. A series of accurate measurements of the chief New Zealand timber-trees, giving both height and girth, is much to be desired.

LXXIX. ORCHIDACEAE.

Spiranthes australis Lendl.

• Near Kaitaia; *R. H. Matthews!* Waipapakauri and Rangaunu Heads; *H. Carse.* Sphagnum swamps at Waihi, Ohinemuri County; *H. B. Devereux!*

Thelymitra ixioides Swz.

This has been gathered by *Mr. J. H. Harvey* at Taumarere, Bay of Islands.

Thelymitra decora Cheesem.

Taumarere, Bay of Islands *J. H. Harvey!* Tirau, Upper Thames Valley: *T. F. C.*

Corysanthes Matthewsii Cheesem.

Mossy slopes in shaded localities near Fairburn. Mangonui County, *H. Carse!* Aponga. Whangarei County; *A. Thompson.*

LXXXII. Liliaceae.

Cordyline australis Hook. f.

A specimen measured by *Mr. E. Phillips Turner* at Tuiangaarere was 15 ft. in circumference at a height of 4 ft. above the ground.

LXXXIV. Palmaceae.

Rhopalostylis sapida Wendl. & Drude.

Another remarkable instance of a branched nikau-palm has been brought under my notice by *Mr. J. R. Lambert,* of Towai, Bay of Islands. It was discovered by *Mr. A. Ingster* in the Ramarama Valley, near Towai, and has no less than seven well-developed branches.

Mr. P. G. Morgan, of the Geological Survey, has supplied me with some interesting information respecting the present southern limit of the nikau in Westland. From particulars obtained from some of the oldest settlers it appears that the most southerly station was near the New River, about eight miles south of Greymouth. In this locality it has been destroyed by the spread of settlement, but it still exists, although in small quantity, at Nelson Creek, about four miles south of Greymouth. North of the Grey River, Mr. Morgan states from his own observations that it is still fairly plentiful on both the eastern and western slopes of the Rapahoi or Twelve Apostles Range, which runs northwards from Greymouth to Point Elizabeth. In this locality it ascends to an elevation of from 700 ft. to 800 ft. Northwards of Point Elizabeth it is comparatively abundant along and near the coast, and is in no immediate danger of disappearance through the spread of settlement and cultivation.

XCI. Cyperaceae.

Mariscus ustulatus C. B. Clarke.

Miss Chase informs me that this occurs in small quantity in Half-moon Bay, Stewart Island. It is not mentioned in Dr. Cockayne's list of the flora of the island.

Uncinia caespitosa Boott.

Hilly forests near Kaitaia, Mangonui County; *H. Carse!* The most northern locality yet recorded.

XCII. Gramineae.

Paspalum Digitaria Poir.

Mr. Carse informs me that this is spreading rapidly in the Fairburn-Kaitaia district. No doubt it is a comparatively recent immigrant.

XCIII. FILICES.

Hymenophyllum subtilissimum Kunze.

Stretches as far north as the Maungataniwha and Kaitaia Ranges Mangonui County, *H. Carse!*

Trichomanes strictum Menz.

On the margins of holes dug in extracting kauri-gum in open tea-tree country near Mangatete, Mangonui County, *H. Carse!* A very remarkable locality, as the species is almost invariably a denizen of the deep forest. Shaded mossy places near the summit of the Little Barrier Island. 2,200–2,400 ft. altitude; *T. F. C.*

Davallia novae-zealandiae Col.

Vicinity of Kaitaia, Mangonui County; *H. Carse.* Not previously known to the northwards of the Bay of Islands.

Lomaria nigra Col.

Dark ravines near Fairburn, Mangonui County, and from thence to Hokianga: *H. Carse.* A marked northwards extension of the range of this species.

Asplenium Trichomanes Linn.

Limestone rocks by the Marikopa River, Kawhia County; *E. Phillips Turner!* Not previously recorded to the northwards of Mount Egmont.

Asplenium umbrosum J. Smith.

Alluvial flats between Fairburn and Kaitaia, Mangonui County: *H. Carse.* The most northern locality yet recorded.

Polypodium dictyopteris Mett. (**P. Cunninghamii** Hook.).

Mr. Phillips Turner has forwarded specimens of a curious crested form obtained at Wilton's Bush, near Wellington.

Psilotum triquetrum Swartz.

Karangahake Cliffs, Western Bay, Lake Taupo, *H. Hill!* A somewhat unexpected locality, all the stations previously recorded to the south of the Waikato River being on soil heated by hot springs.

NATURALIZED PLANTS.

Geranium Robertianum Linn.

Roadsides at Ruatangata, Whangarei; *T. F. C.* Slopes of Mount Eden, Auckland; *F. Neve!*

Soliva sessilis Ruiz and Pavon.

This has increased considerably of late years in light warm soils in the Auckland District, and has become a troublesome weed in some localities, particularly in certain market-gardens at Onehunga.

Tolpis umbellata Bertol.

Sandy soil on the west coast near Helensville, Kaipara; apparently increasing; *T. F. C.*

Lactuca muralis E. Mey.

Wangapeka Valley, Nelson; *F. G. Gibbs!* The first record for the species in the Nelson Provincial District.

Linaria Cymbalaria Mill.

This has become extensively naturalized on the lava-fields surrounding the base of Mount Wellington, Auckland; *T. F. C.*

Verbena bonariensis Linn.

I am indebted to *Mr. T. S. Crompton* for specimens of this collected in the vicinity of New Plymouth. Mr. Crompton informs me that he has seen it in several localities within a radius of six to eight miles from the town.

Ottelia ovalifolia L. Rich.

Since I first recorded the existence of this species in New Zealand (Trans. N.Z. Inst., vol. 31 (1898), p. 350) it has appeared in many of the streams and lakes of the Auckland Provincial District, stretching from the Auckland isthmus southwards to the Upper Waikato and Waipa. It has become specially abundant in Lakes Waikare and Whangape, and in most of the slow-running tributaries of the Waikato from Huntly to the mouth of the river. It is difficult to account for its rapid spread, except on the assumption that seeds or young plants have been conveyed by aquatic birds, for although its spread along the Waikato River may be due to floods transferring plants or seeds, that explanation will not suffice to account for the appearance of the plant in such isolated localities as Lake Takapuna, Chelsea, Hunua, Waitakarei River, &c.

Apera spica-venti Beauv.

Mr. Petrie has shown me specimens of this collected by him in the immediate vicinity of Auckland, and informs me that he has observed it in the Provincial District of Otago. So far as I am aware, it has not been previously recorded from the Southern Hemisphere.

Art. XXV.—*Preliminary Note on the Fungi of the New Zealand Epiphytic Orchids.*

By T. L. Lancaster, Sir George Grey Scholar, Victoria College, Wellington.

Communicated by Professor Kirk.

[*Read before the Wellington Philosophical Society, 7th September, 1910.*]

The epiphytic orchids found in New Zealand comprise six species, all of which are endemic. The four genera to which they belong are typically tropical, two (*Sarcochilus* R. Br. and *Bulbophyllum* Thouars) being widely distributed in tropical regions. *Dendrobium* Swartz has its headquarters in the Malay Archipelago, while *Earina* Lindl. extends to the islands of the

tropical Pacific. The species specially referred to in this paper are *Dendrobium Cunninghamii* Lindl., *Earina mucronata* Lindl., and *Earina suaveolens* Lindl.

If transverse sections of the roots of *Earina* or *Dendrobium* be examined with the microscope it will generally be found that some of the cortical cells contain each a yellowish-brown mass. Sometimes these masses are few in number and small in size, but often they are present in abundance and are conspicuous objects in the section. They are most plentiful in the outer layers of cortical cells, and are seldom found in close proximity to the stele. Close examination of these masses shows that they vary greatly in size, in shape, and in the materials composing them. In colour and denseness, too, they show variation, so that no two are alike, even in the same cross-section. It will be of assistance in description to refer all these masses to one or another of three chief classes, into which they may be divided, the first class containing masses which consist almost wholly of a more or less dense coil of well-defined fungal hyphae; the second comprising those which are dense and yellowish in colour, and in which no traces of hyphae are observable; and a third class consisting of masses which are intermediate in structure between those of the first two classes. The bodies belonging to the last class are usually composed partly of numerous granular bodies and partly of what are evidently degenerating fungal hyphae.

In the bodies of the first type the hyphae are thin-walled, almost colourless, often swollen slightly in places, and are usually coiled up in a more or less dense mass. They are septate, the division walls being sometimes very numerous, and they often branch freely. A vacuolated appearance is nearly always observable, and sometimes the hyphae are seen to have collapsed in places.

The masses of the second class, although varying greatly in shape, generally have their edges well defined. They are usually of a yellowish colour, and the substance of the mass appears homogeneous, no signs of fungal hyphae being observable. Each of these masses is usually connected with the walls of the cell in which it occurs by one or more narrow strands, which often appear to consist of protoplasm, but which are sometimes fungal hyphae in a state of degeneracy. Sometimes the strands belonging to the masses in adjacent cells appear to be continuous through the dividing cell-walls, so that the strands would seem to connect the yellowish bodies with one another.

The masses of the third class contain numerous degenerating hyphae, the outlines of which are often difficult to distinguish, and mingled with these are often large numbers of tiny granular bodies. Sometimes small starch-grains are present among these, but they are never abundant. Often the central portion of these masses is of a yellowish colour, and more dense than the outer portions, which consist largely of degenerate hyphae; in fact, if it were not for the presence of this outer hyphal layer the mass could be correctly referred to class 2. It should have been stated at the outset that it is not possible absolutely to delimit these classes from one another, as they are connected by masses of intermediate structure.

In the cortical cells containing the bodies just described the nucleus is frequently much swollen, and it is generally observed to be in close contact with the mass in the cell to which it belongs—sometimes, indeed, it appears to be partly included in the mass. Usually bodies belonging to all three of the above types will be seen in any one section, but one class of mass

invariably predominates. In most cases the bodies coming under the second head will be found to be most numerous.

An examination of the velamen tissue of these orchid-roots shows that it almost invariably contains many colourless or brownish hyphae, which branch freely and wander through its cells, forming a loose network of mycelial threads. The hyphae are septate, and it would sometimes appear from their great variation in thickness that more than one species of fungus was present. This is undoubtedly often the case. At maturity the velamen is a dead tissue, and no coils of hyphae or yellowish masses such are seen in the cortical cells are present in it. Where the hyphae are present in abundance in the velamen that tissue is sometimes observed to be in a state of decay; indeed, in the older portions of some roots it has entirely disappeared, and the exodermis is then the outermost layer.

The passage-cells of the exodermis are often occupied by a scanty coil of hyphae formed by threads which have entered from the velamen. Sometimes a mass of granular bodies occupies each of these cells, which, unlike those of the velamen, contain living contents. Where extensive thickening has taken place in the exodermal cells it is not always easy to demonstrate the connection existing between the hyphae of the transfusion-cells and those of the velamen, owing to the presence of a felty mass which often guards these cells on their outer sides. The transfusion-cells of the exodermis are the ones which admit the fungal hyphae to the cortical tissues. Having entered one of these passage-cells, a hypha usually forms a loose coil, and then extends out into the cortex, where it may branch, and each branch is generally seen to end in one of the yellowish masses above described. Sometimes after forming a coil in one cell a hypha enters an adjacent cell, where it forms another coil, and it may do this in several cells in succession. The hyphae which are found in the cortex are seldom normal, and they generally present an unhealthy and impoverished appearance. This ill-nourished condition is indicated by the presence of vacuoles, and often by the collapse of the hyphal walls. The hyphae of the velamen never have this unhealthy appearance.

Where the roots of these orchids come into contact with humus, as they usually do in the crevices of the bark of the supporting tree, or in the black material formed by the decay of lichens, mosses, &c., it is noticed that numbers of hairs, much resembling the root-hairs of ordinary terrestrial plants, are frequently developed. Sometimes among the other normal hairs some will be seen which have become flattened, and then twisted in a regular spiral fashion. The cavity of each hair usually contains one or more fungal hyphae, which are continuous with those in the velamen.

The foregoing description applies in all essential respects to both species of *Earina* and to *Dendrobium Cunninghamii*, in which the velamen is usually a well-marked tissue, and the roots of which are structurally very similar. In the New Zealand species of *Bulbophyllum* and in *Sarcochilus adversus* the velamen is poorly developed, being seldom more than two cells deep. In *Sarcochilus* the hyphae of the velamen are very scanty, but the yellowish masses in the cortical cells are often large and abundant.

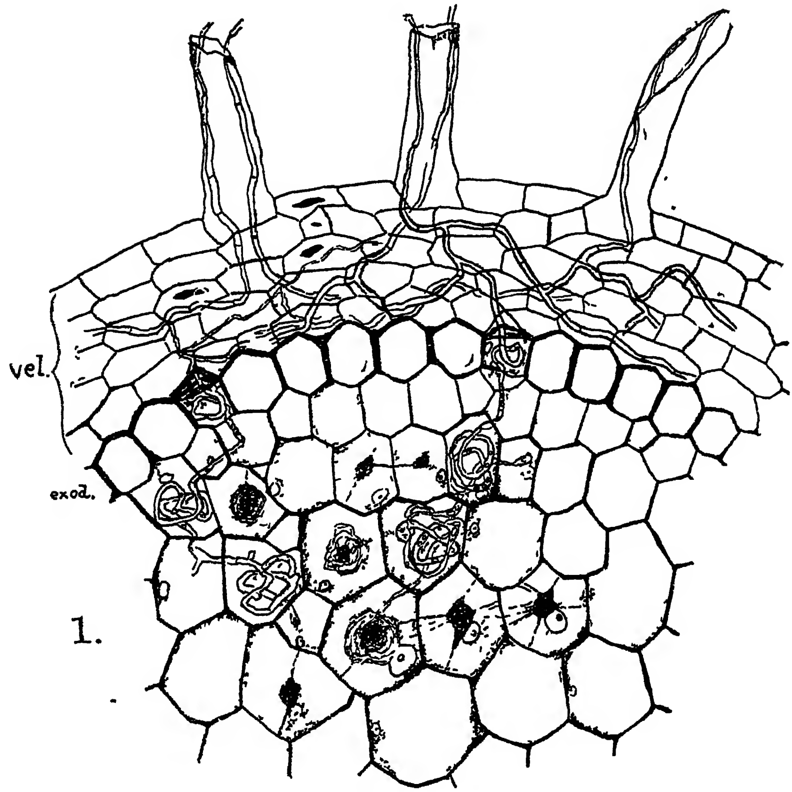
It is by no means easy to discover the exact physiological significance of structures such as those briefly described, although such problems are of supreme interest. It is well known that the roots of many plants growing in soils rich in humus often live in intimate connection with the mycelia of fungi inhabiting the soil. These associations are believed to be beneficial to both organisms, and to such an alliance between the roots of one of the

higher plants and a fungal mycelium the name "mycorhiza" is given. Mycorhizae are of two kinds—those in which the fungal elements do not penetrate the root, but merely form a dense mat round it, and those in which the hyphae enter the root and form coils within its cells. There can be no doubt that the relationship existing between the roots of our epiphytic orchids and the fungal filaments comes under the head of mycorhizic associations. It is evident, moreover, that the mycorhizae in their case are endotrophic. Orchids seem to be particularly prone to the formation of such alliances, and it is therefore not surprising to find that some New Zealand orchids possess mycorhizae. Among mycorhizae hitherto described is that of a British saprophytic orchid, *Corallorhiza innata*, which was dealt with by Messrs. Hanna and Jennings in a paper published in the "Proceedings of the Royal Dublin Society" (1898).

There is little fixity of opinion as to the exact nature of the benefits accruing to the partners in these mycorhizic associations. The view of Hanna and Jennings with regard to *Corallorhiza* is that the hairs found on the rhizome of the plant are produced with the object of attracting the fungal hyphae into the rhizome, so that the orchid can use them to augment its supply of food-materials. According to these authorities, the coils of hyphae in the orchid's cells are gradually absorbed as food by the protoplasm, starch-grains appearing in abundance as the hyphae disappear. A view held by Groom and Janse with regard to endotrophic mycorhizae in general is that the fungus is digested by the root, thereby supplying combined nitrogen. Other investigators—*e.g.*, Hiltner and Magnus—hold similar views.

In the case of the New Zealand orchids it is not probable that the hairs on their roots are produced as fungus-trapping organs. In some cases it is certain from the manner in which the hyphae branch that they are leaving, and not entering, the root. In many instances spores have been seen in the hairs, and in more than one case the cavity of a hair at its extremity was observed to be densely packed with spores. What seems more probable is that the hairs perform, for a time at least, the functions which root-hairs perform in ordinary terrestrial plants—viz., absorption of water and mineral food. As above mentioned, the velamen at maturity is a dead tissue: its cells after having thickened their walls in a curiously intricate fashion lose their living contents, so that the hairs springing from them must also die, and presumably become functionless. It seems probable that no special significance is to be attached to the presence of the hyphae in the hairs. That the fungi sometimes use them as a means of entering the root cannot be doubted, but it is very likely that the hyphae are capable of penetrating the velamen at almost any point, and that their chief mode of entrance is by direct penetration of the outer cells of that tissue.

It is well known that humus is invariably penetrated in all directions by the hyphae of many species of fungi, and these are believed to assist in breaking down the complex organic compounds of the humus, thereby bringing a large amount of plant-food into an available condition. The humus, from which these epiphytic orchids must obtain practically all their food-materials except carbon, is formed, as before stated, largely by the decay of lower plants, chiefly lichens and mosses. It is unlikely that the carbon of the humus is utilized by the orchids, as they are all well supplied with chlorophyll, and it would therefore seem that their supply of carbon from atmospheric sources would be adequate to their needs. It cannot be said that their supply of available nitrogen is by any means



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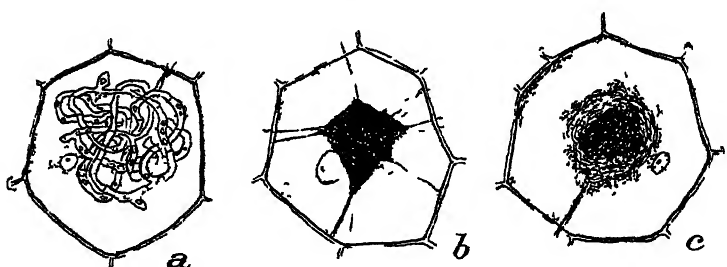

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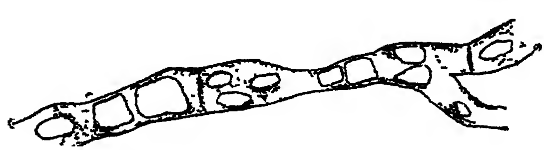


1. Portion of a transverse section of the root of *Earina mucronata*, showing the hyphae in the velamen and the masses in the cortical cells. The thickenings of the walls of the velamen cells have been omitted to secure clearness.
2. Cells from the cortex, showing the hyphae in various stages of absorption—*a*, first stage; *c*, intermediate stage; *b*, third stage.
3. Portion of a hypha from the cortex, showing vacuolated appearance (much enlarged).

sufficient. The nitrogen compounds of humus are in general far too complex for ordinary green plants to assimilate. In view of this fact the idea that the fungus of the mycorhiza in some way assists in increasing the nitrogen-supply does not seem unreasonable, and the experimental work of British and Continental investigators tends to show that there are good grounds for this supposition, at least in the case of the particular plants investigated by them.

With regard to the New Zealand epiphytic orchids, it is impossible in the absence of experimental investigation to make any positive statements as to the uses of the mycorhiza. In view of the evidence in hand, however, the following may be held to represent in a general way what occurs, and to be a brief statement of the working hypothesis :—

Fungal hyphae living in the humus in which the orchid-roots are usually imbedded penetrate the spongy velamen tissue and wander about in its cells, and probably derive some slight advantages therefrom. It has been remarked above that this tissue is sometimes found to be in a state of decay. That the hyphae may have something to do with this is not impossible. In this dead velamen tissue they meet with no active resistance. Finding points of weakness in the exodermal cylinder—*e.g.*, the transfusion-cells—they enter. Here, however, they are for the first time face to face with vigorous living cells, and after forming a scanty coil they branch out into the cortex. The orchid now becomes the aggressor, and its protoplasm absorbs what it can from the hyphae, producing in them the vacuolated appearance previously mentioned. After forming several coils in the cortical cells the hyphae are exhausted, and the protoplasm of the orchid still continuing to absorb, eventually kills them. It soon changes a dense coil of filaments into a yellowish unorganized mass, which probably represents the parts of the fungus which the protoplasm is slow to assimilate, or which it is unable to assimilate. The nuclei of the cortical cells show the result of the vigorous nutrition in their greatly increased size. The three types of masses above described represent the coils of hyphae in different stages of absorption. The observation of a very large number of sections of the roots shows that something like this is actually what occurs. The appearance of a mycorhiza is held by some to indicate incipient saprophytism. If this view is correct, the New Zealand epiphytic orchids may be just beginning a career as saprophytes.

The position of the fungi of these mycorhizae in the classificatory scheme has not yet been determined. Culture experiments have been made, but I do not regard their results as absolutely convincing. I am hopeful, however, that a few more experiments of this kind will enable the systematic positions of the fungi to be accurately determined. It is worthy of note that spores are often observable in the velamen tissue, especially in the older portions of the roots, and most commonly when the roots are freely exposed to the air. In several cases the whole of the hyphae in the velamen had broken up into chains of spores.

ART. XXVI.—*The Rediscovery of* Ranunculus crithmifolius *Hook. f.*

By ROBERT M. LAING, B.Sc.

[*Read before the Philosophical Institute of Canterbury, 7th December, 1910.*]

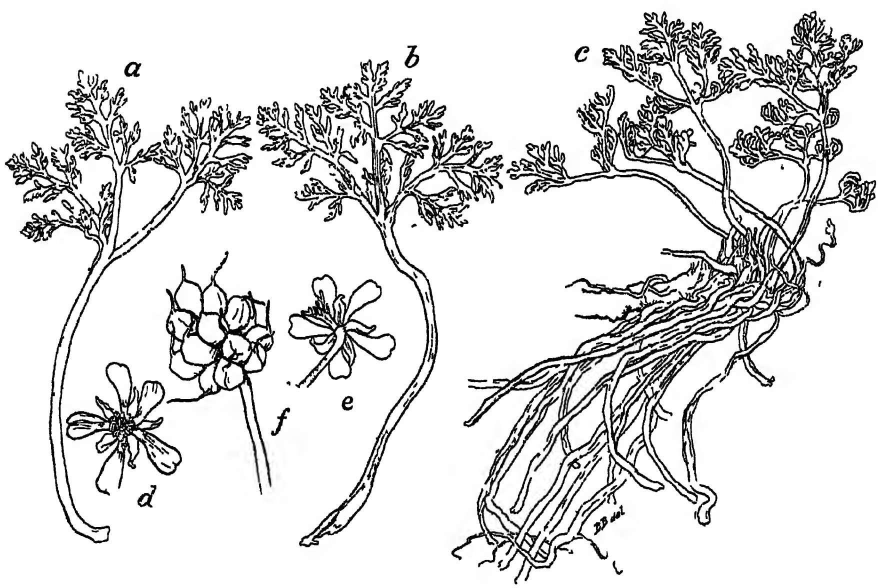
IN the "Handbook of the New Zealand Flora" (1864), by Sir J. D. Hooker there is described as a new species *Ranunculus crithmifolius*. It was collected by Mr. W. T. L. Travers at the Wairau Gorge, at an altitude of 6 000 ft. Hooker adds to his description the note that it is "a very singular plant, easily recognized by its glaucous, fleshy habit, finely divided leaves, and single-flowered short scapes." Mr. T. Kirk, in his "Students' Flora of New Zealand" (1899), quotes Hooker's description, and adds—I know not on what authority—the remark that only one specimen of the plant was found by Travers. In Cheeseman's "Manual of the New Zealand Flora" (1906), under the description appears the note, "A curious little plant, which has not been collected since its original discovery nearly forty years ago. There are no specimens in any of the New Zealand herbaria, and I have consequently reproduced Hooker's description."

In the "Plants of New Zealand," 1906, p. 170, alluding to this plant, I wrote thus: "In spite, however, of all the perseverance and research of modern workers, a few of the forms apparently known to the earliest explorers have not been rediscovered in recent times. In some cases it is probable that the plant has been redescribed under a fresh name; in a very few cases it may be that by some lucky chance the first collectors found a plant that on account of its extreme rarity has never been seen again. In *Ranunculus crithmifolius* we have a plant that has not been reidentified since first found by Travers on the shingle-slips of the Wairau Gorge. Even then only a single plant was seen. It seems more than likely, therefore, that the plant was a casual variant of some other form than really a distinct species. If, however, the original description is to be trusted, *Ranunculus crithmifolius* is one of the most remarkable species of the genus. Like all other shingle-slip plants, it is highly specialized: otherwise it would not have been able to live in the place whence it was reported. . . . It has leaves which, on a smaller scale, closely resemble those of the rock-samphire, a plant of an altogether different order. They are thick, succulent, bluish-green, and highly polished, thus differing widely from the normal leaf-form of the genus. Diels compares them to the leaves of *Ligusticum carnosulum*, which is one of the most singular species of the flora, and also [along with *Ranunculus Haastii*] grows on the same shingle-slips in the Wairau Gorge."

From these extracts it will be seen that *Ranunculus crithmifolius* was what sailors call a "vigia"—something once reported but not again seen. In January, 1910, I visited the Mount Arrowsmith district, and followed up the course of a little stream flowing into the Cameron River on the westward side of the Cameron Hut. The source of the stream was in a shingle-covered ridge, some 5,000 ft. high. On the western side of this ridge I was delighted to find a plant with all the characteristics of the shingle-slip species, but one which was new to me. Specimens of it were scattered, a few yards apart, over an area of several acres. It was by no means common, and a close search was necessary to find it, as the leaves were of the same colour as the shingle. Near at hand was growing *Ligusticum*

carnosulum, and although *Ranunculus Haastii* was not seen on the same shingle-slip it is to be found in the district. A careful search revealed scapes that had done flowering and showed the plant to be a *Ranunculus*, and on taking it back to camp it was found to agree in every detail with Hooker's description of *Ranunculus crithmifolius.* It is strange that a plant which had been lost for nearly fifty years should be obtained about a hundred and fifty miles away from its first-discovered habitat, but still in association with the same species originally found in its vicinity. A long search failed to reveal any flowers, and only a few achene-bearing plants were found.

A little needs to be added to the original description. Some living specimens were obtained, and one or two of these were given to Mr. J. R. Wilkinson, of Bushside, Mount Somers. He has been able to grow them,



a, b. Leaves; half natural size.
c. Plant; half natural size.
d. Flower, from front; half natural size.
e. Flower, from back; half natural size. One sepal has become leaflike.
f. Fruit; magnified twice.

and forwarded me, on the 20th September of this year, a fully expanded flower. I am thus able to give a more complete description of the plant than has hitherto been possible, for Travers's specimen was in fruit only.

The horizontal rootstock, which is about 1 cm. in diameter, sends out at intervals loose rosettes of 6–8 leaves, which die down in the autumn. When mature the leaves are 6–10 cm. high, and of the usual grey-green of the plants of the shingle-slip. The petioles are 5–7 cm. long, channelled, and end in a somewhat membranous yellow-brown leaf-sheath, about 2 cm. in length. The leaf is usually ternately divided, the petiolule about equalling the blade in length. The latter is more or less triangular in outline, and

3–4 cm. broad at the base. The secondary segments are pinnately rather than ternately subdivided, and are also more or less triangular in outline. The ultimate divisions are linear, obtuse, 2–3 mm. long, and about 1 mm. broad. At Mount Somers the plant flowered in September, while the leaves were still unfolded and closely appressed to the shingle.* The scape is short, 1–2 cm. long; flowers 2–3 cm. in diameter. Sepals (5) oblong, inbricate in the bud, pale cream, truncate, 8–10 mm. long, tinged on the under-surface with pale brown. Petals (5) cuneate, slightly emarginate, yellow above, streaked with brown below, with a single large glandular pit at the base of each. When the flower is fully expanded the petals are remote, and admit the full breadth of the sepals between them. Stamens numerous, filaments short, about half the length of the petals. The turgid achenes, about 12–20 in number, form a rounded head 8–10 mm. in diameter. All parts of the flower are quite glabrous.

Though no original specimens have been seen, the identity of the plant with that of Travers can scarcely be doubted. I have deposited a specimen in Canterbury Museum.

Art. XXVII.—*On the Flora of the Mangonui County.*

By H. Carse.

[Read before the Auckland Institute, 22nd November, 1910.]

The County of Mangonui is situated in the extreme north of the Auckland Provincial District. It lies between 34° 20′ and 35° 20′ south latitude, and consists of a long narrow peninsula stretching north-west known as the North Cape Peninsula, and a southern portion more or less oblong in shape. The peninsula is about fifty miles in length, and from five to ten miles across. The lower portion is about forty miles from east to west, and averages about sixteen miles from north to south.

"The first person to explore the district from a natural-history point of view was the veteran botanist Mr. Colenso, who in 1839 travelled from Kaitaia northwards to Cape Maria van Diemen, and from thence to the Reinga, Spirits Bay, and the North Cape. During this journey he collected several of the plants peculiar to the district, notably *Hibiscus diversifolius* and *Lycopodium Drummondii*, the last of which has not been refound.† In 1840–41 Dr. Dieffenbach, the naturalist to the New Zealand Company, made an exploration of the country to the north of the Bay of Islands. He

* Since writing the above I have seen specimens of the flower in Dr. Cockayne's garden in Christchurch. On my return to Christchurch last January I gave him one or two living plants of *R. crithmifolius*. These have grown quite readily in ordinary soil at the low altitude of Christchurch. The leaves are less appressed to the surface of the ground and the scapes are much longer than in the specimen grown by Mr. Wilkinson.

† Since refound by Mr. H. B. Matthews.

spent a considerable time in the North Cape Peninsula, judging from the account given in his 'Travels in New Zealand,' where Chapters 12 and 13 are devoted to the physical features and geology of the district. I cannot learn that he made any botanical collections therein, but the chapters quoted contain several interesting remarks upon the vegetation. In the summer of 1865–66 the district was visited by Sir James Hector. . . . He was accompanied by Mr. John Buchanan, who made a considerable collection of plants, which I believe was forwarded to Kew. He was the first to detect *Hymenanthera latifolia*, and observed several other species not previously recorded from that part of New Zealand. In April, 1867, Mr. Kirk and the late Mr. Justice Gillies made a brief visit to the district between Parengarenga Harbour and Spirits Bay. Notwithstanding the lateness of the season, a few novelties were collected and much additional information obtained. Some notes on this journey will be found in the 'Transactions of the New Zealand Institute' (vol. 1, p. 143). A list of the plants observed by Mr. Buchanan and Mr. Kirk is given in vol. 2 of the same publication (pp. 239–46). So far as I am aware, these three papers comprise all that has been published on the botany of the North Cape Peninsula."*

In the Transactions for 1896 appears a paper "On the Flora of the North Cape District" by Mr. Cheeseman, from which I have taken the foregoing paragraph. Mr. Cheeseman in his paper mentions his earliest visit to the district, in 1874, when he explored Doubtless Bay, Oruru Valley, Maungataniwha, and a portion of the east coast. In 1889 Mr. Cheeseman again paid a short visit to the district, followed in 1896 by a longer one. His itinerary shows that on this occasion he passed from Mangonui to Awanui, thence to Kaitaia and Ahipara, and thence coastwise northwards as far as the North Cape. Considering the short time available, Mr. Cheeseman was able to take note of a considerable number of plants.

Since the time of Mr. Cheeseman's visits a fair number of botanical discoveries have been made; indeed, it would be surprising if during the fourteen years that have elapsed a considerable amount of additional information as to the plant covering of the district had not been gained. As a resident in the district, and a not unsuccessful observer of nature, I am in a position to supply additional botanical information, partly from my own observations and partly from those of my friends Messrs. R. H. and H. B. Matthews and Mr. H. Bedggood. As a rule, however, these new discoveries were made in parts which were not included in Mr. Cheeseman's trip.

It is not my intention to deal with the northern portion of the county, but only with the lower part which lies south of a line through Mount Camel and Cape Karakara.† This includes the southern portion of the North Cape Peninsula.

The lower section of Mangonui County has a broken coast-line on the east and north, Doubtless Bay and Rangaunu Bay being the chief openings. The west coast for many miles is unbroken until Ahipara Bay is reached. Here the coast suddenly trends towards the west to Reef Point, more generally known by the Native name of Tauroa. Here it turns south, then south-east to the Herekino River, the south-western boundary of the county.

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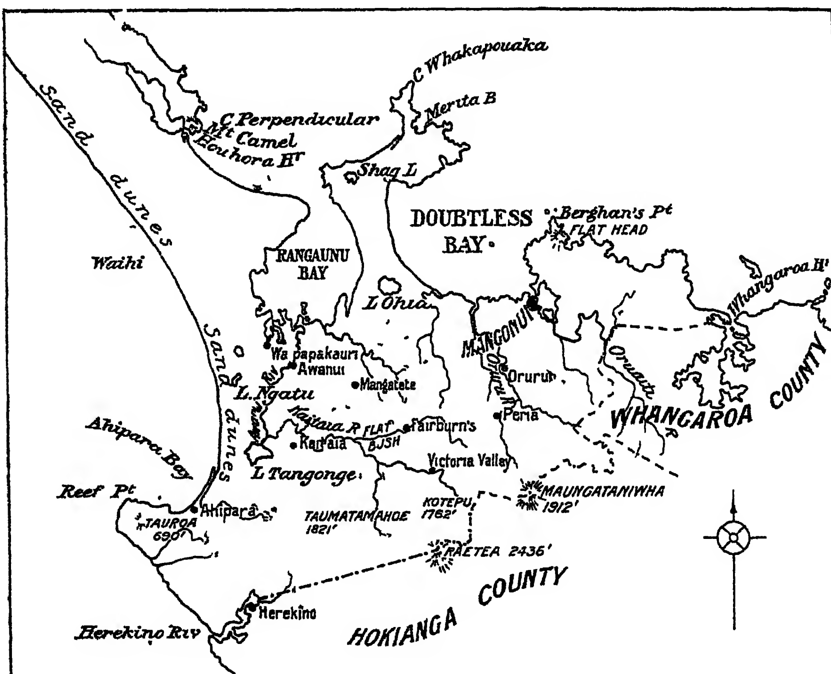
* Cheeseman: "On the Flora of the North Cape District," Trans. N.Z. Inst., vol. 29, p. 333.

† This is really Cape Whakapouaka; there is a stream called Karikari a few miles away.

North-west from Ahipara the coast-line consists of a range of sand-dunes, consolidated and recent, on the landward side of which are smaller sand-dunes, among which are numerous small lakes and lagoons. Inland from these are extensive peat-swamps, and farther inland firmer flat land, subject to inundation during the heavy rains. From Ahipara southward the coast-line is more rocky. The Tauroa Peninsula, which terminates in Reef Point, is chiefly a series of elevated sand-dunes, rising to a height of about 700 ft. From the Tauroa Plateau radiates a fanlike series of hills towards the north and east.

The first line of hills runs parallel with the coast, at an average distance of five miles, from the Tauroa towards Awanui and Mangatete. There are two breaks in this line—the Herekino Gorge, through which run a small river and the road to Herekino; and the Kaitaia Valley, which extends towards the east, and branches into the Victoria, Takahue, and Fairburn



Sketch-map of Part of Mangonui County.

(Scale, twelve miles to an inch.)

Valleys. The highest point in this range is Taumata Mahoe (1,881 ft.). Between Kaitaia and Mangatete this high land spreads out, forming a table-land at an elevation of about 600 ft. From this plateau ranges of hills run through Fairburn towards Oruru and Mangonui, the highest point being Kopu Okai, commonly known as Trig. 27 (1,063 ft.), a few miles from Fairburn.

Eastward the county is broken but less elevated until we come to Raetea (2,436 ft.), the highest point in the county; from thence runs a range to

Kotepu (1,762 ft.), overlooking Victoria Valley. Behind this range are the Maungataniwha Ranges, branching out from the hill of that name (1,912 ft.).

It will thus be seen that the central and southern portion of the district is very broken. High hills and deep valleys, heights almost mountainous, separated by profound gorges or deep gullies, form the chief features from a bird's-eye view. This is the forest country of the district, and here, in spite of the axes of the settler and bushman, many miles of bush-clad ranges are still to be seen.

It has been pointed out how the plants of any locality are not arranged by chance, but are found in definite combinations, called technically "plant formations," which have come into existence in consequence of the geological history of the region, the climate, the nature of the soil, and other causes, some physical, others biological.*

If we take a bird's-eye view of this or of almost any district we find that the plant covering may be arranged into six more or less clearly defined plant formations. These are the forest, the moorland, the swamp, the lake and river, sea cliffs and beaches, and sand-dunes. In many cases, no doubt, these forms, or some of them, are more or less merged into others, but generally speaking their differences are clearly marked and the species belonging to one formation keep to their own places, though vagrant forms do at times intrude upon their neighbour's domain.

THE FOREST FORMATION.

Less than a century ago the greater part of southern Mangonui was covered with dense forest. The axes of the settler, clearing the land for purposes of grazing and cultivation, and of the bushman, felling the trees for timber, are rapidly making the forest primeval a thing of the past, but there is still left standing sufficient of the old forest to give us a good idea of what it consists.

For p rposes of botanical study the forest formatio 1 may be divided into three classes—the general bush, the kauri bush, and the kahikatea bush.

The general bush varies more or less in its constituents according to soil, elevation, slope, &c. By far the most common tree in this section is the taraire, so much so that the name "taraire bush" is almost as applicable to it as the names "kauri" and "kahikatea" to the sections in which these trees predominate.

In the taraire bush—as, in fact, in all bush—the covering consists of tall trees, many of which bear, or are more or less covered by, epiphytic plants and interlacing lianes, of smaller trees, shrubs, and tree-ferns, with a carpet of creeping and other herbs, grasses, sedges, ferns, mosses, &c. In addition to the taraire, the more prominent trees are totara, rimu, miro, matai, tawa, hinau, rewarewa, towai, kohekohe, &c. Of the smaller trees and shrubs, mahoe, *Hedycarya*, *Fusanus*, various species of *Coprosma*, and in damp places *Fuchsia* and pate (*Schefflera*), are the most common. The surface covering, besides ferns, mosses, and allied plants, is made up of sedges, grasses, orchids of various species; and in many places *Nertera dichondraefolia*, creeping and rooting as it goes, forms a characteristic feature. Of sedges, the most prominent are *Gahnia xanthocarpa* and *G. setifolia.* The principal native grasses to be seen are *Microlaena avenacea* and *Oplismenus undulatifolius.* Of the orchids I shall speak later.

* "Report on a Botanical Survey of the Tongariro National Park," L. Cockayne, Ph.D., F.L.S., &c.: Department of Lands, Wellington, 1908.

Of the lianes, the most noticeable are the bush-lawyer (*Rubus*) and supplejack (*Rhipogonum*). These are frequently found stretching to the tops of the tallest forest-trees, in such a position that we can only conclude that they have attached themselves to the branches when the tree was young and have grown up with the growth of the tree. Sometimes, however, in place of ascending, these plants form an almost impenetrable network through which neither man nor beast can pass. Other lianes are various forms of rata-vines (*Metrosideros*). *Parsonsia*, *Clematis*, kiekie, &c.

In damp places on creek-banks and on wet slopes great masses of *Elatostemma rugosum*, a succulent-stemmed prostrate herb with large vari-coloured leaves, is a characteristic covering.

Of epiphytes growing on the forest-trees the commonest and most noticeable are forms of wharawhara (*Astelia*), among which various ferns and lycopods are frequently found. On trunks and upper branches, too, occur a few orchids—*Earina* (two species), *Dendrobium*, *Bulbophyllum*, and *Sarcochilus*. A prominent epiphyte is the rata-tree in its earlier life. As a seedling it is often found in the clefts of branches of tall trees. As it grows it sends branches upward and root-stems downward; these, reaching the ground, into which they penetrate and branch off, absorb nutriment, causing their upper parts to swell out into trunks, coalescing one with another until they crush out the life of the tree which for years gave them support. The rata (*Metrosideros robusta*) will, and often does, grow as a terrestrial plant, but when growing directly from the soil never forms a large tree—rarely, indeed, exceeding 25 ft. or 30 ft. in height. On Rangitoto Island, near Auckland, the rata growing among blocks of lava forms shrubs only.

Other epiphytes which grow in a more or less similar manner are *Griselinia lucida*, whose large glossy leaves are often prominent objects in the upper branches of tall trees; *Panax arboreum*, usually on tree-ferns;* and a few others.

It may not be out of place here to draw attention to the mistake often made by many people of confusing the words "epiphyte" and "parasite." Epiphytes, as the name denotes, merely live *upon* other plants, but derive nothing in the way of nourishment from the substance of the supporting plants, nor do their roots penetrate that substance. Parasites, on the other hand, derive their food in part or entirely from the sap of the plant on which they grow, and into whose substance their roots penetrate, or to whose surface they apply their sucking-discs. We have not many parasite plants in this district. *Loranthus micranthus* and *Korthalsella salicornioides* are not infrequent, and the curious leafless *Cassytha paniculata* occurs plentifully on *Leptospermum* near the coast, attaching itself to its victim by means of small suckers.

The Kauri Forest.

In the kauri forest that tree towers high above all others. There are, as a rule, few other large trees, the most frequent being the towai (*Weinmannia sylvicola*), a few taraires, kawakas (*Libocedrus Doniana*), miro, and tanekaha (*Phyllocladus trichomanoides*). Of smaller trees and shrubs the most conspicuous is the neinei (*Dracophyllum latifolium*); others are species of *Coprosma*, maire, *Myrtus pedunculata*, *Panax anomalum*, &c.

Perhaps the most conspicuous feature of the kauri bush is the great quantity of kauri-grass (*Astelia trinervia*), among which occur *Astelia*

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* Carse: "On the Occurrence of *Panax arboreum* on the Stems of Tree-ferns," Trans. N.Z. Inst., vol. 34, p. 359.

nervosa, and the large sedges *Gahnia xanthocarpa* and *G. setifolia*, which, owing to the sharply serrated edges of their leaves, form a somewhat formidable barrier. The ferns *Dicksonia lanata*, *Gleichenia Cunninghamii*, *Lomaria minor*, and the curious *Schizaea dichotoma* also occur. A very conspicuous plant in the kauri forest is *Metrosideros albiflora*, whose large glossy leaves and racemes of pure-white flowers make it a plant well worthy of a place in our wild gardens.

The Kahikatea Bush.

The kahikatea, or white-pine, is usually found in colonies in damp, often swampy, land. It occurs in the higher lands, but never in large quantities. In the kahikatea bush the undergrowth is very dense, the greater part being formed of numerous species of *Coprosma*. Other common plants are mahoe, *Hoheria*, *Plagianthus*, *Pennantia*, kowhai, &c. The native passion-vine (*Passiflora tetrandra*), *Parsonsia heterophylla*, and *P. capsularis* also occur.

Of the surface-plants, the most common are various forms of sedges (*Carex* chiefly), *Hydrocotyle* of various species, and numerous ferns, mosses, and grasses.

THE MOORLAND.

The moorland consists of open country, usually of a stiff clay formation, destitute of trees. Much of this land ages ago was covered with kauri forest. Of this we have the evidence of old kauri stumps and roots, and the gum which has for many years given employment to a great number of men.

Much of this land is covered with tea-tree, usually small, owing partly to frequent fires sweeping over the surface and partly to the poverty of the soil. Among the tea-tree scrub are found several forms of *Lycopodium*, orchids, and sedges. Larger sedges also cover large areas.

Conspicuous on many of these moorlands are *Pomaderris elliptica* (kumarahou), with its beautiful cymes of creamy-yellow flowers; *P. phylicaefolia*, a heath-like plant; *Dracophyllum Urvilleanum*; and of smaller plants, forms of *Haloragis*.

In damp and swampy parts of the moorlands are found the dainty bladderworts *Utricularia delicatula* and *U. novae-zealandiae*, the sundews *Drosera binata* and *D. spathulata*, and very rarely the orchid *Spiranthes australis*.

THE SWAMP.

The most noticeable plant of the swamps is undoubtedly the raupo (*Typha angustifolia*), whose densely clustered pale-green leaves form masses visible for miles. Here, too, on the firmer parts, occurs the useful *Phormium tenax*, or New Zealand flax, the conversion of which gives employment to so many of our people. Several species of *Hydrocotyle* are frequent creeping on the surface, as also does *Ranunculus rivularis* (the whauriki), a small buttercup containing an acrid poison, often fatal to stock. Another conspicuous swamp-plant is the large willow-herb, *Epilobium pallidiflorum*. Round the margin, and often through the swamp, occur large masses of the pink-flowering *Polygonum serrulatum*, and *Sparganium antipodum*.

The coast swamps vary somewhat from the inland ones. These are usually formed by the blocking-up of a small creek by the inroads of the sand from the beach. In the maritime swamps of this district are to be found, in addition to most if not all of the inland-swamp plants, *Plagianthus divaricatus*, *Epilobium chionanthum*, *Hibiscus diversifolius*, *Lemna minor*, *Triglochin striatum*, &c., and the ferns *Nephrodium unitum* and *N. Thelypteris*.

Lake and River.

Of the plants occurring in or about lakes and rivers we may make two classes—viz., those that grow on muddy banks, which as a rule fall naturally under the head of swamp-plants; and, secondly, those which germinate in the mud at the bottom, and rise up to produce flowers and fruit on the surface. And yet it is not at all possible to lay down hard-and-fast rules on this point, for the plants of the mud-banks not infrequently grow entirely submerged, and those of more aquatic habits are often found in drier situations, usually, however, in a more or less depauperated condition.

On the margins of lakes and rivers where the soil is muddy most of the swamp-plants—raupo, flax, sedges, &c.—are found. In addition are *Glossostigma elatinoides* (often forming dense matted patches), *Elatine americana*, *Callitriche verna*, and various forms of *Epilobium*.

In the beds and at the sides of inland creeks the rocks which rise above the water form the habitat of *Epilobium pedunculare*, in dense dark-green masses, among which not infrequently occur the dainty orchid *Corysanthes rotundifolia*, with its one leaf and helmet-shaped purple flower, and the little daisy *Lagenophora petiolata* var. *minima*. Here and there occurs the somewhat rare *Nertera Cunninghamii*. Conspicuous on many of these creeks, among the rocks, occur the graceful plumes of the tall grass *Arundo fulvida*, closely allied to the beautiful and larger *Arundo conspicua*, so characteristic of the coast.

Of the more or less submerged plants the most common are forms of *Myriophyllum* and *Potamogeton*. Entirely submerged are the various forms of the order *Characeae*, chiefly species of *Nitella*.

Along the banks of tidal creeks the tall *Scirpus maritimus* is a prominent object, and at their mouths, among mud-banks, are found mangroves.

Sea Cliff and Beaches.

Among the more prominent plants on or near the sea cliffs and beaches may be mentioned the pohutukawa (*Metrosideros tomentosa*), whose brilliant crimson flowers make the coast-line beautiful in early summer, giving to this plant the name of Christmas-tree; the karaka, whose fruit formed a great addition to the food of the old-time Maori; the tawapou (*Sideroxylon costatum*), sometimes called the New Zealand olive, from the resemblance of its fruit to that of the olive (the true New Zealand olive is the maire—*Olea*). Here and there along the coast is found *Fuchsia procumbens*, a graceful little plant, differing from all its congeners in the flowers being upright instead of drooping. In a few places are found the rare *Coprosma Kirkii*, which will probably become extinct within the present generation.

Among smaller plants, very conspicuous are *Cladium Sinclairii*, a sedge with broad ensiform leaves and large drooping brown panicles; *Cassinia retorta*, *Pimelia arenaria*, *Olearia furfuracea*, and more rarely *Olearia angulata*, all bearing white flowers.

Among the herbs may be mentioned the wild celery (*Apium prostratum*), *Samolus repens*, *Sonchus asper* var. *littoralis*, and *Ipomaea palmata*, with its lovely convolvulus-like flowers.

Among the distinctly arenarian plants are *Gunnera arenaria*, *Tetragonia* (New Zealand spinach), *Crantzia lineata*, *Tillaea Sieberiana*, &c. *Atriplex patula* and *Salsola Kali* are increasing, especially the latter. There is, I think, little doubt as to these species being introduced, though they have become so widely distributed that it is difficult to distinguish these and a few others from aboriginals.

SAND-DUNES.

The most striking plant of the sand-dunes is undoubtedly the tall plume-grass *Arundo conspicua*. Other plants peculiar to this situation are *Coprosma acerosa* var. *arenaria*, *Scirpus frondosus*, *Euphorbia glauca*, and *Spinifex hirsutus*, all of which are more or less useful in repelling the inroads of the sands.

In sandy places at no great distance from the sea is found the tiny sundew *Drosera pygmaea*. This "charming little gem"* has been reported from various localities from Cape Maria van Diemen to Ahipara. inland from Kaitaia to Ahipara, and also from Bluff Hill in Southland. So far no botanist has seen it between these widely severed habitats. In many places where the forest has been cleared, and the land has not been sown in grass, or has been neglected, dense masses of fern (*Pteris*) cover the soil. Low-lying grass lands will, if neglected, be smothered in wiwi (*Juncus effusus*) in a few years.

TOPOGRAPHICAL BOTANY.

It may be interesting now to take a few localities more particularly—localities in which plants of special interest have been found. The first I will refer to is the Tauroa. This is a tableland built up of consolidated and drifting sands, rising from Reef Point to a height of about 700 ft. At one time there were many kauri-trees growing on this plateau, the stumps of which still remain. In sheltered gullies running down from the upper level are remains of the original forest covering, consisting now of small woods, rapidly, alas! becoming buried in the ever-advancing sands. This locality has been very thoroughly explored by Messrs. R. H. and H. B. Matthews and Mr. H. Bedggood, and has yielded up many interesting botanical finds. Among these are *Myrtus Ralphii* and *M. obcordata*, of which the previous known northern limit was Whangarei Heads; *Pseudopanax ferox*, a rather rare plant; *Corokia* sp., which is, I believe, similar to one found by Mr. Cheeseman in the North Cape district, which may prove a new species; † *Lagenophora pinnatifida*, not before known north of Helensville, Auckland; *Earina mucronata*, variety with broader leaves, denser panicle, and larger flowers; *Microlaena polynoda*, extending its habitat north from Whangarei Heads.

"Lake Tangonge is the largest of a chain of lakes situated on the western side of the Awanui River, almost fringing the coast-line of sandhills. It is about three miles in length by perhaps half that width, but is surrounded by a much larger area of raupo swamps, most of which are filled with water during the greater part of the year."‡

In or near this lake have been found several very interesting plants, thanks to the investigations of Messrs. R. H. and H. B. Matthews. Of these perhaps the most interesting is *Lycopodium Drummondii*. "This plant, which was referred to *L. carolinianum* in the Handbook, was gathered within the district by Mr. Colenso in 1839, but unfortunately the exact locality has been forgotten."§

Another interesting plant of this locality is *Lepyrodia Traversii*, previously reported only from the Middle Waikato district and the Chatham Islands; and another rare plant is *Pterostylis micromega*, found in swamps

* "Students' Flora," Kirk, p. 146.
† "Manual of the New Zealand Flora," T. F. Cheeseman, F.L.S., F.Z.S., p. 238.
‡ "On the Flora of the North Cape District," T. F. Cheeseman, F.L.S., F.Z.S.: Trans. N.Z. Inst., vol. 29, p. 343.
§ *Loc. cit.*, p. 382.

on the margin of the lake. In a few places in the lake itself are found plants of *Utricularia protrusa*. This is only the third locality known in the Dominion. The somewhat rare sedge *Scirpus lenticularis* is also found here; and on the margin of the marshy land Mr. R. H. Matthews discovered *Carex Brownii*, a small sedge, not previously known as a native of New Zealand.

Where the waters of the lake flow out into the Kaitaia-Awanui River Mr. Matthews made one of the most interesting finds that botanic science has known for many years: this was the rediscovery of *Pittosporum obcordatum*. But for the fact that I had climbed up a cabbage-tree a few minutes earlier for the purpose of getting a view over the high raupo, &c., I might have scored this point; but the main point is that this long-lost species *was* rediscovered. It was originally reported by Raoul from Akaroa, but has not been seen since in that locality.

Within a short distance of this spot are found several specimens of *Plagianthus cymosus*, a rather rare plant. For some time only one tree was known in this locality, but later several others were found.

Scattered throughout the district are other plants of considerable interest to botanists for their rarity or from their being found in habitats much farther north of any previously reported.

On the sandy margin of Lake Ngatu, a small lake situated behind the coastal sand-dunes a few miles from Awanui, I had the good fortune to discover a tiny annual herb belonging to the order *Centrolepideae*. It was provisionally described in the Manual as *Trithuria inconspicua*. Later, in a paper read before the Auckland Institute, 3rd October, 1906, Mr. Cheeseman placed this plant in the genus *Hydatella*, a genus of three species, two found in Western Australia, the third endemic in New Zealand.*

The koru (*Colensoa physaloides*), the leaves of which were used by the Natives in the early days in place of cabbage, occurs sparingly in several places. It is usually found among damp shady rocks, never as a rule at any great distance from the sea. It has been reported from Mount Camel, Merita Bay, Ahipara, the Toatoa, a deep ravine inland from Doubtless Bay, and near Herekino.

In addition to the submerged bladderwort (*Utricularia protrusa*) found in Lake Tangonge, two smaller ones (*U. novae-zealandiae* and *U. delicatula*) occur in peaty swamps in several localities. The former is reported by Mr. Cheeseman from near Lake Ohia; I have also found it on a peaty slope near Kaitaia. The latter, a dainty little plant, is more plentiful, occurring in peaty swamps near Kaitaia, on both sides of Rangaunu Harbour, and on the Peria gum-hills.

In Flat Bush, a low-lying piece of land between Kaitaia and Fairburn, I discovered the sedge *Carex dipsacea*. This is plentiful in Manukau County, but has not been reported from any locality farther north until I found it. Probably it does occur between these distant points, but has been overlooked.

The Westland pine (*Dacrydium Colensoi*), which is not uncommon along the west coast of the South Island, is found in the North Island at a few widely separated spots only from Ruapehu to the far north. One mature tree and a sprinkling of young ones occur in a kauri bush a few miles from Fairburn. I am told that another tree is known near Victoria Valley, but I have not seen it.

* "Notice of the Occurrence of *Hydatella*, a Genus new to the New Zealand Flora," by T. F. Cheeseman, F.L.S.: Trans. N.Z. Inst., vol. 39, p. 433.

Up to the present the Peria gum-hills, a tract of barren country traversed by the road from Mangonui to Kaitaia, is the only known New Zealand habitat of the sedge *Lepidosperma filiforme.*

Another plant of only one known habitat in the Dominion is the grass *Imperata arundinacea*, one of Mr. R. H. Matthews's finds. *Viola Lyallii*, a dainty little violet, occurs sparingly in the district. It is usually found in damp shady situations. It has been reported from Kaitaia, Flat Bush, and not far from the Double Crossing Bridge between those localities. It probably occurs elsewhere in suitable situations, but may easily be overlooked.

Galium umbrosum, a small usually prostrate plant, often forming large green matted masses in woods, is peculiar here for its rarity. In many places it is one of the most common species, but so far it has only been noticed in Victoria Valley, Flat Bush, and the Tauroa, and only a few plants have been seen.

Myosotis spathulata, a small forget-me-not, has up to the present been found only in Kaitaia. The leaves of this plant, one of Mr. R. H. Matthews's finds, is more rounded and less spathulate than is usually the case, but this species is very variable.

In referring to the ferns, I omitted to mention *Trichomanes strictum.* So far as is at present known, this is one of the rarest ferns in the district. The only place where I have seen this species in the Mangonui County is on the moorland lying north from Kaitaia. The few plants I saw were growing on the edges of "potholes"—*i.e.*, small pits from which gum has been dug—a rather unusual situation. I believe one plant was found in a small wood in the same neighbourhood.

ORCHIDS.

There are twenty-one genera of orchids in New Zealand, divided into fifty-seven species. Of these, four species are epiphytic, as are most of the orchids of the tropics, and the rest are terrestrial. Our orchids do not by any means equal their tropical congeners in gorgeousness of colouring or eccentricity of form, though many of them are beautiful, but, as a rule, small. Of the twenty-one genera, we have eighteen in this district; of the fifty-seven species, we have thirty-five.

Botanists are greatly indebted to Mr. R. H. Matthews, of Kaitaia, for the careful and useful work he has done in this section of botany. To Mr. Matthews is due the discovery in the Mangonui district of *Bulbophyllum tuberculatum*, *Thelymitra ixioides*, *T. intermedia*, *Pterostylis micromega*, *P. barbata*, *Caleana minor*, *Calochilus paludosus*, *Caladenia minor* var. *exigua*, *Chiloglottis formicifera*, *Corysanthes Cheesemanii*, *C. Matthewsii*, and *Gastrodia sesamoides.*

The epiphytic orchids which are, as a rule, found on the branches of tall forest-trees are *Dendrobium Cunninghamii*, a diffusely branching plant, with stems like miniature bamboos, narrow leaves, and white or pinkish flowers; *Earina*, two species, with rather heavily scented flowers; *Bulbophyllum*, two species, both tiny plants, with leaves issuing from pseudobulbs, from the base of which grow the flowers. Of these, *B. tuberculatum* is much more rare than the other. *Sarcochilus*, a rather thick-leaved plant, is plentiful on the upper branches of trees, and not infrequently on the trunks.

The terrestrial species are found in various situations. *Spiranthes* occurs in swamps in several localities. *Thelymitra*, of which there are eight or

nine species in New Zealand, is represented in this district by five or six species (I understand a new species was discovered by Mr. Matthews this year). Most of these are moorland-plants. The flowers of this genus are less like the generally accepted idea of orchids than any other. The genus "is remarkable from the lip being quite free from the column and resembling the petals and sepals, so that the perianth has little of the irregular appearance of an orchid, but rather resembles that of an *Ixia* or a *Sisyrinchium*."* Of the *Thelymitrae* the most showy and one of the most common is *T. pulchella*, easily distinguished by the large blue-purple flowers. *T. ixioides* and *T.* sp. nov. are the rarest of the genus. What I take to be Berggren's *T. intermedia* is not uncommon on old clay landslips and hillsides.

Orthoceras, which is not uncommon on dry banks, is rather a curious-looking plant. The flowers, which grow in the form of a spike, bear a general resemblance to a number of grasshoppers climbing up a stick. *Microtis porrifolia*, a common orchid in almost all situations, bears a close resemblance to the next genus, *Prasophyllum*, of which there are two species in the district. Both are moorland-plants, and not uncommon. I think the one now included under *P. Colensoi*, will prove to be a different species. Mr. Cheeseman, referring to it in a letter, says, "Your plant is not quite identical with the southern plant, but until a very careful comparison can be made of the structure of the flowers . . . they are best kept together."

Caleana minor, a rare plant, is found on barren-looking moorland near Kaitaia. "A most remarkable little plant. The column is horizontally placed, forming a broad pouch; the lamina of the lip, when at rest, is elevated by the slender elastic claw, and swings directly above it. When an insect alights on the lamina it overbalances, shutting up the insect within the concavity of the column."†

The flowers of *Pterostylis*, of which we have five out of the eleven species found in the Dominion, are also insect-traps; they are in form like boat-shaped hoods. *P. Banksii* and *P. graminea* are common in forests, and *P. trullifolia* plentiful on moorlands and dry open ridges in the bush. *P. micromega* is a rare swamp-orchid; *P. barbata*, another rare plant. So far the latter two are only known in this district near Kaitaia. *Acianthus*, a very small plant, is one of the commonest orchids we have; it is usually found in humus in the bush. *Cyrtostylis*, a small delicate orchid, is not uncommon; usually on dry ridges. *Calochilus paludosus* is another rather rare orchid; Kaitaia is one of the six places in the Dominion from which it has been reported. On clay hills from Kaitaia to Fairburn occurs a slender form of *Caladenia minor*, which Mr. Cheeseman has distinguished as var. *exigua*. Another of Mr. Matthews's discoveries was *Chiloglottis formicifera*, previously only known from eastern Australia. *C. cornuta* also occurs, but is not common.

Of *Corysanthes*, six of the seven species occur. The flower resembles a helmet in shape, and is, as a rule, of a deep-purple colour. They are all shade-loving plants. In the Manual *C. Cheesemanii* is reported from "Kaitaia; vicinity of Auckland; Westport." This is a small plant, easily overlooked, and probably not uncommon in open bush and scrub throughout. I found a few specimens at Mauku, in Manukau County; it occurs also in Fairburn, but is rare. Of *C. Matthewsii*, originally found at Kaitaia, I

* "Manual of New Zealand Flora," p. 668.
† *Ibid.*, p. 677.

have specimens gathered by Mr. A. Thompson at Aponga; it is not uncommon on mossy slopes near Fairburn. *C. oblonga* is not uncommon on clay banks and slopes. *C. rivularis,* in my opinion the handsomest of the genus, is very local; so far I have only seen it in one spot in Mangonui County, between Fairburn and Peria. *C. rotundifolia* is plentiful, though rather local; its favourite habitat is on banks of bush-creeks, or on rocks in the bed of the creek. *C. triloba,* which in many places in common, is rare in this district; Mr. Matthews found two or three specimens, young plants only, near Kaitaia.

Gastrodia sesamoides was found by Mr. Matthews near Kaitaia and Tauroa, the only places in Mangonui County from which it has been reported.

Ferns and Allies.

Of ferns and allied plants there are in New Zealand about 156, of which ninety-nine are in Mangonui County. The majority of these are more or less common from the North Cape to the Bluff, but a few are worthy of a word or two, for one reason or another.

Loxsoma Cunninghamii, as a rule rather a rare fern, is fairly plentiful in several localities, though there are often considerable areas from which it is absent. *Lomaria Banksii,* a very local plant, occurs sparingly on the west coast. In dark ravines from near Fairburn towards Hokianga I have found *L. nigra,* not previously reported from north of Whangarei. *Asplenium japonicum* occurs in considerable quantity on alluvial banks of streams in Fairburn, and less plentifully near Kaitaia. *Nephrodium unitum,* at one time supposed to occur only in the thermal regions (in New Zealand), is not uncommon in swamps, generally near the sea, but inland at Lake Tangonge along with *N. Thelypteris.* The rarer *N. molle* was also discovered by Mr. Matthews near Mangatete. In sandy gullies and other suitable places, never far from the sea, *Todea barbara* is plentiful. This is a very local plant in New Zealand, occurring only from Whangaroa northward. It is a very different-looking plant from *Todea hymenophylloides* and *Todea superba,* the fronds of which are filmy. These belong to the section *Leptopteris. Todea barbara* reminds one of the royal fern, *Osmunda regalis,* of the Northern Hemisphere. The para (*Marattia fraxinea*) is not uncommon in gullies in the Maungataniwha Ranges.

Lycopodium Drummondii, already referred to, so far as is known has only one habitat in New Zealand, near Kaitaia, where Mr. H. B. Matthews rediscovered it, probably at the same spot where Mr. Colenso originally collected it in 1839. The rare and curious lycopod *Psilotum triquetrum* was collected by Mr. R. H. Matthews near Rangaunu Harbour and at Merita Bay, the only places north of Rangitito Island, Auckland, from which it is recorded.

Plants suitable for Cultivation.

I regret that I have not yet been able to explore the two highest points in the county—viz., Raetea and Maungataniwha. I have seen something of the spurs leading from them, and I hardly think that the height of Raetea (2,436 ft.) justifies our expecting any very marked change in the plant covering; but, still, it would be of some interest to be sure on this point.

There are certain plants in the district which from their beauty of foliage or flower, or for the sweetness of their perfume, are worthy of a place in our gardens. Several of the species of *Pittosporum* are already well known in cultivation. *P. virgatum* would be a very interesting plant owing to the

remarkable changes through which the leaves pass from the young to the mature state.

Hibiscus trionum and *H. diversifolius* are both well worthy a place in the flower-garden, more especially so that they are becoming rarer each year, cattle destroying them to such an extent that where at one time they were plentiful now they are unknown.

Entelea arborescens, with its large leaves and handsome flowers, is a fine addition to the shrubbery.

On the clay hills in many parts the large corymbose panicles of bright yellow or cream-coloured flowers of *Pomaderris elliptica* lend colour to the landscape in September. The flower-buds of this plant form in December and take till September before they open. The fruit is ripe about November.

For the wild garden, any almost of the different species of *Metrosideros* (rata-vines) would be suitable, particularly *M. albiflora*, with its large green leaves and wide-spreading panicles of white flowers; or *M. diffusa*, with bright-crimson flowers; or *M. florida*, with its orange-red (sometimes yellow) flowers.

Place certainly should be given to the various forms of *Alseuosmia*, the true honeysuckle of New Zealand. In my opinion, the scent of this flower is more delicious than that of any other indigenous plant. Nor is scent the only recommendation, for the shining leaves and the flowers themselves are attractive to the eye. There are four species: *A. macrophylla*, with leaves 3–7 in. long, and crimson (sometimes white) flowers 1–2 in. long; *A. quercifolia*, similar, but smaller; *A. Banksii* and *A. linariifolia*, smaller and smaller still. There are certain forms of *Alseuosmia* which a mere beginner can place at a glance as typical, but there are so many forms intermediate between the various species that hardly two botanists in a dozen will agree as to which species predominates in the particular specimen. Another remarkable feature of this plant is the curious imitative faculty it possesses in its leaves. I have specimens whose leaves in shape, though not in size, have a striking resemblance to those of a great many other plants, among which may be mentioned the oak, hawthorn, *Myrtus bullata* (the "bubbled" leaves being exactly imitated), *Hedycarya*, *Pittosporum pimeleoides* (type, and var. *reflexum*), tawa, taraire, *Coposma* of various species, &c.

Colensoa physaloides, with its large light-green leaves and racemes of large pale-blue or purple-blue flowers, is suitable for shaded rockeries. It grows readily from seed in damp sheltered situations.

Ipomoea palmata, with its graceful twining stems and white or purple convolvulus-like flowers, is, I think, already included in the lists of flower-seeds.

Veronica macrocarpa and *V. diosmaefolia* form handsome shrubs.

Either of the species of *Muehlenbeckia* would be useful in covering an unsightly corner, owing to rapidity of growth and abundance of foliage.

One of our handsome conifers, especially in the young state, is the kawaka (*Libocedrus Doniana*). It will do well in the open, if not exposed too much to the wind.

Floristic Details.

In the subjoined catalogue of the indigenous plants of the southern portion of Mangonui County, flowering-plants and ferns (including lycopods), will be found the names of 538 species. Compared with the number of species in the Dominion as shown in the introductory part of the Manual, this seems rather a poor showing. The number there given for New Zealand, including the Kermadec and Chatham Islands, is 1,571 species, so that the plants

of this district represent one-third of the total number for the Dominion. I think, when we consider how rich and varied is the plant covering of the South Island when compared with that of the North Island, we may conclude that 538 species is " not so bad."

Of the 97 natural orders of plants known in New Zealand 86 are found in this district, divided into 251 genera.

Of the 86 orders, the largest are *Filices*, with 99 species ; *Cyperaceae*, 51 ; *Orchidaceae*, 35 ; *Gramineae*, 31 ; *Compositae*, 30 ; *Rubiaceae*, 21 ; *Myrtaceae* and *Liliaceae*, 14 each.

Of the genera, the largest are *Coprosma*, with 16 species ; *Carex*, 14 ; *Pittosporum* and *Hymenophyllum*, 10 each ; *Lomaria* and *Polypodium*, 9 each ; *Epilobium*, *Asplenium*, and *Juncus*, 8 each ; *Metrosideros*, *Scirpus*, and *Cladium*, 7 each.

CATALOGUE OF THE FLOWERING-PLANTS AND FERNS OBSERVED IN THE SOUTHERN MANGONUI DISTRICT.

[N.B.—The initials " T. F. C." indicate that the plant appears in the Manual, but that I have not found it in the locality named.]

Ranunculaceae.

Clematis indivisa Willd. Common throughout.
„ *foetida* Raoul. Ahipara ; Broadwood ; Fairburn.
„ *parviflora* A. Cunn. Common in hilly country.
Ranunculus hirtus Banks & Sol. Abundant.
„ „ var. *elongatus* Cheesm. Common in wet places.
„ *rivularis* Banks & Sol. Common in wet places.
Ranunculus acaulis Banks & Sol. Brackish-water marshes and moist sandy shores ; plentiful.

Magnoliaceae.

Drimys axillaris Forst. In forests, Fairburn ; Victoria Valley.
Drimys axillaris var. (pps. intermediate between above and *D. colorata* Raoul). Kaitaia ; rare.

Cruciferae.

Nasturtium palustre D. C. Not uncommon in wet places.
Cardamine hirsuta L. Plentiful in damp land.
„ *stylosa* D. C. Kaitaia ; Fairburn ; rare.

Violaceae.

Viola Lyallii Hook f. Flat Bush, Kaitaia ; not common.
Melicytus ramiflorus Forst. Abundant throughout.
„ *macrophyllus* A. Cunn. Common in hilly bush.
„ *micranthus* Hook. f. Common in lowland forests.
Hymenanthera latifolia Endl. Mount Camel. T. F. C.

Pittosporaceae.

Pittosporum tenuifolium Banks & Sol. Abundant.
Pittosporum Buchanani Hook. f. Kaitaia and Mangonui. (This has not been seen in the district since Buchanan's visit.)
Pittosporum obcordatum Raoul. Near Kaitaia ; rare.
Pittosporum virgatum T. Kirk. High country near Kaitaia ; coast south of Mangonui. T. F. C.

Pittosporum crassifolium A. Cunn. On coast and small islands; rare.
Pittosporum umbellatum Banks & Sol. Mangonui Harbour and coast. T. F. C.
Pittosporum Kirkii Hook. f. Maungataniwha Range.
,, *cornifolium* A. Cunn. Abundant in forests.
,, *pimeleoides* R. Cunn. In hilly forests, chiefly among kauri.
,, *eugenioides* A. Cunn. Oruru; not common.

Caryophyllaceae.

Stellaria parviflora Banks & Sol. Not uncommon.
Colobanthus Billardieri Fenz. West coast (R. H. Matthews). Reported from Houhora by Mr. Buchanan. T. F. C.

Elatinaceae.

Elatine americana Arn. var. *australiensis* Benth. Muddy places on margins of swamps and rivers; not uncommon.

Malvaceae.

Plagianthus divaricatus Forst. Abundant in salt-water marshes.
,, *cymosus* T. Kirk. Near Kaitaia; rare.
,, *betulinus* A. Cunn. In damp lowlands; common.
Hoheria populnea A. Cunn. Abundant in lowlands.
Hibiscus trionum L. Sheltered places near the sea. Rapidly disappearing.
,, *diversifolius* Jacq. Moist sandy places near sea; rare.

Tiliaceae.

Entelea arborescens R. Br. Not uncommon.
Aristotelia racemosa Hook. f. Abundant.
Elaeocarpus dentatus Vahl. Plentiful throughout.
,, *Hookerianus* Raoul. Kaitaia; rare.

Linaceae.

Linum monogynum Forst. Along the coast; not common.

Geraniaceae.

Geranium dissectum L. var. *australe* Benth. Abundant.
,, *microphyllum* Hook. f. On dry open land; not uncommon.
,, *molle* L. Common throughout.
Pelargonium australe Jacq. Common throughout.
Oxalis corniculata L. Abundant.
,, *magellanica* Forst. Mangonui and Kaitaia. T. F. C.

Rutaceae.

Phebalium nudum Hook. Throughout the district, but rare.
Melicope ternata Forst. Plentiful.
,, ,, var. *Mantellii* Kirk. Kaitaia and Victoria Valley.
,, *simplex* A. Cunn. Plentiful in places.

Meliaceae.

Dysoxylum spectabile Hook. f. Abundant throughout.

Olacinaceae.

Pennantia corymbosa Forst. Common in lowlands.

Rhamnaceae.

Pomaderris elliptica Lab. Common on clay hills.
,, *phylicaefolia* Lodd. Plentiful on moorlands.

Sapindaceae.

Dodonea viscosa Jacq. Plentiful.
Alectryon excelsum Gaertn. Common throughout.

Anacardiaceae.

Corynocarpus laevigata Forst. Abundant near sea ; less common inland.

Coriariaceae.

Coriaria ruscifolia L. Common throughout.

Leguminosae.

Carmichaelia australis R. Br. Common.
Sophora tetraptera Mull. Not uncommon in damp woods.

Rosaceae.

Rubus australis Forst. Abundant.
,, *cissoides* A. Cunn. Not common.
,, *schmidelioides* A. Cunn. Plentiful.
Acaena novae-zealandiae T. Kirk. Not uncommon.
,, *Sanguisorbae* Vahl. Abundant.

Saxifragaceae.

Quintinia serrata A. Cunn. Kaitaia ; Mangonui.
Ixerba brexioides A. Cunn. Ahipara and Maungataniwha. T. F. C.
Carpodetus serratus Forst. Margins of swamps and lowland bush.
Ackama rosaefolia A. Cunn. Plentiful.
Weinmannia sylvicola Sol. Abundant.

Crassulaceae.

Tillaea Sieberiana Schultz. Sandy places on coast ; common.

Droseraceae.

Drosera pygmaea D. C. In sandy peat near the sea, scattered ; and inland from Kaitaia to Tauroa.
Drosera spathulata Labill. Wet moorlands ; common.
,, *binata* Labill. Moorland swamps ; common.
,, *auriculata* Backh. Open hillsides ; abundant.

Haloragidaceae.

Haloragis alata Jacq. Generally distributed.
Haloragis tetragyna Hook. The typical form and var. *diffusa* common on moorlands.

Haloragis depressa Walp. Throughout the district.
" *micrantha* R. Br. Common on moorlands.
Myriophyllum intermedium D.C. Abundant in rivers, lakes, and wet land.
Myriophyllum robustum Hook. f. Kaitaia. R. H. Matthews. I have not seen it.
Myriophyllum pedunculatum Hook. f. Moist sandy places near sea: not uncommon.
Gunnera monoica Raoul. Fairburn and Peria; rare.
" *arenaria* Cheesem. Wet sand-dunes along west coast.
Callitriche verna L. Streams and lakes; not uncommon.
" *Muelleri* Sond. Moist shady places; abundant.

Myrtaceae.

Leptospermum scoparium Forst. Abundant.
" *ericoides* A. Rich. Common throughout.
Metrosideros florida Sm. Common in forests.
" *albiflora* Sol. Common in hilly bush.
" *diffusa* Sm. Not uncommon.
" *hypericifolia* A. Cunn. Abundant.
" *robusta* A. Cunn. Common in forests.
" *tomentosa* A. Rich. Plentiful along the coast.
" *scandens* Sol. Abundant.
Myrtus bullata Sol. Common.
" *Ralphii* Hook. f. Tauroa; rare.
" *obcordata* Hook. f. Tauroa; common.
" *pedunculata* Hook. f. Fairburn and Kaitaia.
Eugenia maire A. Cunn. Swampy forests; common.

Onagraceae.

Epilobium pallidiflorum Sol. In swamps; plentiful.
" *chionanthum* Haussk. Ahipara; Waihi.
" *Billardierianum* Ser. Not uncommon; usually near coast.
" *junceum* Sol. Abundant.
" *pubens* A. Rich. Plentiful.
" *alsinoides* A. Cunn. Plentiful in places.
" *rotundifolium* Forst. Damp places; abundant.
" *nummularifolium* R. Cunn. Plentiful.
Epilobium nummularifolium var. *pedunculare* Hook. f. Common on creek-banks.
Epilobium nummularifolium var. *nerteroides* Hook. f. On hillsides; common.
Fuchsia excorticata Linn. f. Abundant throughout.
" *procumbens.* Sandy and rocky places near sea; rare.

Passifloraceae.

Passiflora tetrandra Banks & Sol. In lowland woods; not uncommon.

Ficaceae.

Mesembryanthemum australe Sol. Abundant on rocky coasts.
Tetragonia expansa Murr. Not uncommon on the coast.
" *trigyna* Banks & Sol. Tauroa; not common.

Umbelliferae.

Hydrocotyle elongata A. Cunn. Mangonui; Fairburn; Kaitaia.
,, *americana* L. Not uncommon.
,, *pterocarpa* F. Muell. Common in wet land.
,, *novae-zealandiae* D. C. Abundant.
,, *moschata* Forst. Common on hillsides.
,, *asiatica* L. Abundant throughout.
Apium prostratum Lab. Common on shores.
Apium prostratum var. *filiforme* Cheesm. Occasionally inland; common on shore.
Crantzia lineata Nutt. Abundant in wet sand on coast.
Daucus brachiatus Sieber. Throughout the district; not common.

Araliaceae.

Panax Edgerleyi Hook. f. Hilly forests; not uncommon.
,, *anomalum* Hook. Not uncommon; usually in hilly forests.
,, *arboreum* Forst. Not uncommon.
Schefflera digitata Forst. Abundant in damp gullies.
Pseudopanax Lessonii C. Koch. On coast; not uncommon.
Pseudopanax crassifolium C. Koch var. *unifoliatum* T. Kirk. Abundant in forests.
Pseudopanax crassifolium var. *trifoliolatum* T. Kirk. A few scattered trees only.
Pseudopanax ferox T. Kirk. Tauroa; rare.

Cornaceae.

Corokia buddleoides A. Cunn. Not uncommon; usually in kauri forests.
,, *Cotoneaster* Raoul. Tauroa; in woods.
,, pps. n. sp. Tauroa; in woods; rare.

Caprifoliaceae.

Alseuosmia macrophylla A. Cunn. Abundant in hilly bush.
,, *quercifolia* A. Cunn. Abundant in hilly bush.
,, *Banksii* A. Cunn. Abundant in hilly bush.
,, *linariifolia*, A. Cunn. Not uncommon in hilly bush.

Rubiaceae.

Coprosma grandifolia Hook. f. Abundant.
,, *lucida* Forst. Plentiful.
,, *Baueri* Endl. Common on sea-cliffs.
,, *robusta* Raoul. Abundant throughout.
,, *Cunninghamii* Hook. f. Common in damp lowlands.
,, *arborea* T. Kirk. In high woods; common.
,, *spathulata* A. Cunn. In hilly bush; common.
,, *rotundifolia* A. Cunn. In lowland woods; common.
,, *areolata* Cheesem. Plentiful.
,, *tenuicaulis* Hook. f. Not uncommon.
,, *rhamnoides* A. Cunn. Abundant.
,, *parviflora* Hook. f. Abundant in lowlands.
,, *rigida* Cheesem. Abundant in lowlands.
,, *acerosa* A. Cunn. Abundant on sand-dunes.

Coprosma propinqua A. Cunn. Common in damp places.
„ *Kirkii* Cheesm. West coast; rare.
Nertera Cunninghamii Hook. f. Creek-banks and wet rocks; rare.
„ *dichondraefolia* Hook. f. Abundant in woods.
„ *setulosa* Hook. f. Kaitaia and Ahipara; rare.
Galium tenuicaule A. Cunn. Damp woods and swamps; common.
Galium umbrosum Sol. Tauroa; Victoria Valley: Flat Bush; not common.

Compositae.

Lagenophora Forsteri D. C. Abundant throughout.
Lagenophora petiolata Hook. f. var. *minima* Cheesem. Mangonui and Fairburn.
Lagenophora pinnatifida Hook. f. Tauroa; rare.
„ *lanceata* A. Cunn. Moorlands, Fairburn and Kaitaia.
Olearia furfuracea Hook. f. Common along coast.
„ *Cunninghamii* Hook. f. Abundant in woods.
„ *angulata* T. Kirk. Near the coast, Ahipara, Tauroa.
„ *Solandri* Hook. f. Plentiful near coast, rare inland.
Gnaphalium Keriense A. Cunn. Sides of streams; not uncommon.
„ *luteo-album* L. Abundant throughout.
„ *japonicum* Thunb. Abundant throughout.
„ *collinum* Lab. Common.
Helichrysum glomeratum Benth. & Hook. Tauroa; in woods.
Cassinia retorta A. Cunn. Abundant on coast.
„ „ var. approaching *C. leptophylla*. In woods at Tauroa.
Siegesbeckia orientalis L. Common.
Bidens pilosa L. On coast, Mangonui, Tauroa.
Cotula coronopifolia L. Plentiful in wet places.
„ *australis* Hook. f. Fairburn; Mangonui; not common.
„ *minor* Hook. f. Dripping cliffs at Waihi. T. F. C.
Centipeda orbicularis Lour. Common in wet land.
Erechtites prenanthoides D. C. Common throughout.
„ *arguta* D. C. Common throughout.
„ *scaberula* Hook. Generally distributed.
„ *quadridentata* D. C. Generally distributed.
Brachyglottis repanda Forst. Common throughout.
Senecio lautus Sol. On the coast; common.
„ *Kirkii* Hook. f. Common in forests.
Picris hieracioides L. Common in open dry lands.
Sonchus asper Hill. Common throughout.
„ *oleraceus* L. Common throughout.

Goodeniaceae.

Selliera radicans Cav. Abundant in salt marshes.

Campanulaceae.

Colensoa physaloides Hook. f. Mount Camel; Merita Bay; gullies near Ahipara; Toatoa Gully; Herekino; Maungataniwha Ranges.
Pratia angulata Hook. f. Banks of streams; rather local.
Lobelia anceps Linn. f. Common throughout.
Wahlenbergia gracilis A. D. C. Generally distributed; most plentiful near the sea.

Ericaceae.

Gaultheria antipoda Forst. Common.

Epacridaceae.

Cyathodes acerosa R. Br. Plentiful throughout.
Leucopogon fasciculatus A. Rich. Abundant in open land.
,, *Fraseri* A. Cunn. Common in open country.
Epacris pauciflora A. Rich. Common in open country.
Dracophyllum latifolium A. Cunn. Plentiful in hilly forests.
,, *Urvilleanum* A. Rich. Plentiful in open country.

Primulaceae.

Samolus repens Pers. Common along the coast.

Myrsinaceae.

Myrsine salicina Heward. Common in forests.
,, *Urvillei* A. D. C. Common in forests.
,, *divaricata* A. Cunn. On muddy alluvial banks of Lower Awanui.

Sapotaceae.

Sideroxylon costatum F. Muell. Mount Camel, abundant; several places on coast.

Oleaceae.

Olea Cunninghamii Hook. f. Not uncommon throughout.
,, *lanceolata* Hook. f. Plentiful in forests.
,, *montana* Hook. f. Maungataniwha Range; Fairburn; rare.

Apocynaceae.

Parsonsia heterophylla A. Cunn. Common throughout.
,, *capsularis* R. Br. Not uncommon.

Loganiaceae.

Geniostoma ligustrifolium A. Cunn. Abundant.

Boraginaceae.

Myosotis spathulata Forst. Kaitaia; rare.

Convolvulaceae.

Ipomoea palmata Forst. Along coast; common.
Calystegia sepium R. Br. Abundant throughout.
,, *tuguriorum* R. Br. Plentiful in damp lowland woods.
,, *Soldanella* R. Br. Plentiful on sandy shores.
Calystegia marginata R. Br. Fairburn, not uncommon; Kaitaia, rare; coast near Mangonui.
Dichondra repens Forst. Common.

Solanaceae.

Solanum nigrum L. Abundant throughout.
,, *aviculare* Forst. Abundant throughout.

Scrophulariaceae.

Mimulus repens R. Br. Brackish-water swamp at Waimimiha; rare.
Mazus pumilio R. Br. Wet places, Ahipara; Kaitaia; Waihi; near Awanui.
Gratiola peruviana L. Wet places; not uncommon.
Glossostigma elatinoides Benth. Common in wet places.
Limosella tenuifolia Nutt. Salt marshes; common.
Veronica salicifolia Forst. Common throughout.
,, *macrocarpa* Vahl. Mangonui. T. F. C.
,, *diosmaefolia* R. Cunn. Not uncommon; usually near the sea.
,, *plebeia* R. Br. Open situations throughout; common.

Lentibulariaceae.

Utricularia protrusa Hook. f. Lake Tangonge; near Kaitaia.
,, *novae-zealandiae* Hook. f. Swamps on Lake Ohia; at Kaitaia.
Utricularia delicatula Cheesem. Moorland swamps, Kaitaia; Peria; Mangatete; Rangaunu Harbour.

Gesneraceae.

Rhabdothamnus Solandri A. Cunn. Abundant.

Myoporaceae.

Myoporum laetum Forst. Plentiful, especially on coast.

Verbenaceae.

Vitex lucens T. Kirk. Plentiful throughout.
Avicennia officinalis L. Mangonui Harbour; Rangaunu Harbour; Houhora Harbour.

Labiatae.

Mentha Cunninghamii D. C. Common in damp places, especially near the coast.

Plantaginaceae.

Plantago Raoulii Decne. Common in moist places, especially near the sea.

Illecebraceae.

Scleranthus biflorus Hook. f. Not uncommon in dry places near the sea.

Amarantaceae.

Alternanthera sessilis R. Br. Oruru; near Awanui; Tauroa.

Chenopodiaceae.

Chenopodium glaucum L. Brackish-water marshes; common.
,, *ambrosioides* L. Maori cultivation at Parapara.
,, *carinatum* R. Br. Near Mangonui. T. F. C.
Atriplex patula L. In wet sand, Tauroa. Probably an immigrant.
Rhagodia nutans R. Br. Houhora. T. F. C.
Salicornia australis Sol. Abundant along shores.
Suaeda maritima L. Salt marshes in Mangonui Harbour. T. F. C.
Salsola Kali L. Spreading rapidly along coast. Almost certainly an immigrant.

Polygonaceae.

Polygonum aviculare L. Abundant in moist places. Most probably an immigrant.
Polygonum serrulatum Lag. Abundant on muddy banks of creeks and in swamps.
Rumex flexuosus Sol. Not uncommon in open country.
Muehlenbeckia australis Meissn. Abundant.
,, *complexa* Meissn. Abundant on shores, less so inland.

Piperaceae.

Piper excelsum Forst. Common throughout.
Peperomia Endlicheri Miq. Generally distributed.

Monimiaceae.

Hedycarya arborea Forst. Abundant in forest.
Laurelia novae-zealandiae A. Cunn. Common in wet land.

Lauraceae.

Beilschmiedia tarairi Benth. & Hook. Abundant.
,, *tawa* Hook. f. Common in forests.
Litsaea calicaris Benth. & Hook. Common in forests.
Cassytha paniculata R. Br. Abundant in tea-tree; always near the sea.

Proteaceae.

Persoonia toru A. Cunn. Throughout the district, but never plentiful.
Knightia excelsa R. Br. In forests; common.

Thymeleaceae.

Pimelea virgata Vahl. Not uncommon; usually near the sea.
,, *arenaria* A. Cunn. Abundant on sandhills.
,, *laevigata* Gaertn. Common on moorlands.

Loranthaceae.

Loranthus micranthus Hook. f. Near Kaitaia.
Korthalsella salicornioides Van Tiegh. Near Kaitaia.

Santalaceae.

Fusanus Cunninghamii Benth. & Hook. Common throughout.

Euphorbiaceae.

Euphorbia glauca Forst. Common on sandy shores.

Urticaceae.

Paratrophis heterophylla Blume. Abundant.
Urtica incisa Poir. In damp shady places; common.
Elatostemma rugosum A. Cunn. In damp shady places; abundant.
Parietaria debilis Forst. Not uncommon on coast.

Fagaceae.

Fagus fusca Hook. f. Between Kaitaia and Mangatete. One tree reported. I have not seen it.

Coniferae.

Agathis australis Salisb. Formerly abundant, becoming less so each season.
Libocedrus Doniana Endl. Scattered throughout the forests; never plentiful.
Podocarpus totara D. Don. Plentiful in hilly forests.
,, *Hallii* T. Kirk. Not common in hilly forests.
,, *ferrugineus* D. Don. Common in forests.
,, *spicatus* R. Br. Not uncommon.
Podocarpus dacrydioides A. Rich. Abundant in lowlands; not uncommon in hilly bush.
Dacrydium cupressinum Soland. Abundant.
Dacrydium Colensoi Hook. = *D. westlandicum* Kirk. Near Fairburn, one tree (full grown) and a few young ones; Victoria Valley, one tree ?
Phyllocladus trichomanoides D. Don. In hilly forests; not uncommon.

Orchidaceae.

Dendrobium Cunninghamii Lindl. On upper branches of trees; common.
Bulbophyllum tuberculatum Col. On upper branches of trees, Kaitaia and Fairburn; probably not uncommon throughout.
Bulbophyllum pygmaeum Lindl. On branches and stems of trees; common.
Earina mucronata Lindl. A common epiphyte.
,, *suaveolens* Lindl. Less common than above.
Sarchochilus adversus Hook. f. On trunks and branches of trees; common.
Spiranthes australis Lindl. In swamps. Kaitaia; Waipapakauri; Rangaunu Heads.
Thelymitra ixioides Swz. Kaitaia, common; near Victoria Valley, rare.
,, *longifolia* Forst. Moorlands; common.
,, *intermedia* Bergg. Kaitaia; Fairburn; not uncommon.
,, *pulchella* Hook. f. Moorlands; common.
,, *imberbis* Hook. f. Moorlands; not uncommon.
Orthoceras strictum R. Br. Not uncommon throughout.
Microtis porrifolia R. Br. Plentiful.
Prasophyllum Colensoi Hook. f. On clay hills; not uncommon.
,, *pumilum* Hook. f. On clay hills; not uncommon.
Caleana minor R. Br. On clay hill, Kaitaia; rare.
Pterostylis Banksii R. Br. Abundant in forests.
Pterostylis graminea Hook. f. Fairburn; vicinity of Kaitaia; not uncommon.
Pterostylis micromega Hook. f. Kaitaia; rare.
Pterostylis trullifolia Hook. f. Dry ridges in forest, and on moorland; common.
Pterostylis barbata Lindl. In damp soil among *Leptospermum*, near Kaitaia; rare.
Acianthus Sinclairii Hook. f. Abundant in forests.
Cyrtostylis oblonga Hook. f. Scattered throughout the district.
Calochilus paludosus R. Br. Kaitaia; rare.
Caladenia minor Hook. f. Moorlands and open scrub; common.
,, ,, var. *exigua* Cheesem. Kaitaia; Fairburn.
Chiloglottis cornuta Hook. f. Kaitaia; Fairburn; not common.
,, *formicifera* Fitzg. Kaitaia; rare.
Corysanthes Cheesemanii Hook. f. Kaitaia; Fairburn.
,, *Matthewsii* Cheesem. Kaitaia; Fairburn.

Corysanthes oblonga Hook. f. On damp clay banks throughout.
Corysanthes rivularis Hook. f. Fairburn, in wet part of open forest; not common.
Corysanthes rotundifolia Hook. f. On rocks and creek-banks; not uncommon.
Corysanthes triloba Hook. f. Kaitaia; rare.
Gastrodia sesamoides R. Br. In shaded gully near Kaitaia, rare; edge of swamp, Tauroa.

Iridaceae.

Libertia ixioides Spreng. Ahipara. T. F. C.
,, *grandiflora* Sweet. Throughout the district, but local.
,, *pulchella* Spreng. In hilly forests; not common.

Liliaceae.

Rhipogonum scandens Forst. Plentiful throughout.
Cordyline terminalis Kunth. Represented by two plants in Mrs. Reed's garden at Ahipara, originally growing on the cliffs behind the house.
Cordyline Banksii Hook. f. In places plentiful, but absent from large areas.
Cordyline australis Hook. f. Abundant in lowlands.
,, *pumilio* Hook. f. Ridges in forests and on moorlands; common.
Astelia Cunninghamii Hook. f. Usually epiphytic; abundant.
,, *Banksii* A. Cunn. Cliffs, Hohoura and Rangaunu; not common.
,, *trinervia* T. Kirk. Chiefly in kauri forests; abundant.
,, *Solandri* A. Cunn. Abundant in forests.
Astelia nervosa Banks & Sol. = *A. grandis* Hook. f. Not uncommon; usually in kauri forests.
Astelia sp. ined. A very small plant, not yet identified, ripe fruit not having been seen. On trunks and branches; not uncommon.
Dianella intermedia Endl. Common on dry banks.
Phormium tenax Forst. Lowland swamps, abundant; hilly bush, occasional plants seen.
Arthropodium cirrhatum R. Br. High ranges and sea-cliffs; common.

Juncaceae.

Juncus pallidus R. Br. Fairburn; Broadwood; rare.
,, *pauciflorus* R. Br. Ahipara; Kaitaia; probably not uncommon.
,, *effusus* Linn. Abundant, especially in low-lying country.
Juncus maritimus Lam. var. *australiensis* Buchan. Brackish-water marshes, common; inland swamp near Kaitaia.
Juncus bufonius Linn. Abundant in wet places.
Juncus tenuis Willd. A troublesome weed; has spread greatly. Probably an immigrant.
Juncus planifolius R. Br. Plentiful in wet places.
Juncus lampocarpus Ehr. Has spread rapidly during the last three or four years. A doubtful native.
Luzula campestris D. C. Scattered; nowhere common.

Palmae.

Rhopalostylis sapida Wendl. & Drude. Abundant.

Pandanaceae.

Freycinetia Banksii A. Cunn. In woods; abundant.

Typhaceae.

Typha angustifolia L. Abundant in marshy places.
Sparganium antipodum Graebner. In swamps; abundant.

Lemnaceae.

Lemna minor Linn. Still waters in maritime marshes; common.

Naiadaceae.

Triglochin striatum Ruiz & Pav. var. *filifolium* Buch. Maritime marshes; common.
Potamogeton polygonifolius Pourr. In muddy places: not common.
Potamogeton Cheesemanii A. Bennett. Abundant in streams, lakes, and swamps.
Potamogeton ochreatus Raoul. Kaitaia River; common.
Ruppia maritima Linn. Brackish-water lagoon. Waimimiha.
Zostera nana Roth. Houhora Harbour.
Zostera tasmanica Martens. Common in harbours and on mud-covered rocks; Reef Point.

Centrolepidaceae.

Hydatella inconspicua Cheesem. Sandy margin of Lake Ngatu.

Restiaceae.

Lepyrodia Traversii F. Muell. Swamp near Lake Tangonge; Kaitaia; rare.
Leptocarpus simplex A. Rich. Salt-water marshes and sandy shores; abundant.
Hypolaena lateriflora Benth. In swampy land, Kaitaia; Houhora; Lake Ohia.

Cyperaceae.

Kyllinga brevifolia Rottb. Abundant in damp lowlands. Has spread rapidly.
Cyperus tenellus Linn. f. Abundant throughout.
,, *vegetus* Willd. In damp lowlands; abundant.
Mariscus ustulatus C. B. Clarke. Abundant in lowlands.
Eleocharis sphacelata R. Br. Swamp; common.
Eleocharis neo-zealandica C. B. Clarke. Damp sandy places near the sea; not uncommon.
Eleocharis acuta R. Br. In wet places; abundant.
,, *Cunninghamii* Boeck. In wet places; abundant.
Scirpus lenticularis Poir. Submerged in Lake Tangonge, Kaitaia.
,, *cernus* Vahl. Maritime form abundant; inland form not common.
Scirpus inundatus Poir. vars. *major* and *gracillima*. Both abundant in wet places.
Scirpus nodosus Rottb. Sand-dunes; abundant.
,, *frondosus* Banks & Sol. Sand-dunes; abundant.
,, *lacustris* Linn. Margins of streams and lake; abundant.
,, *maritimus* Linn. var *fluviatilis*. Tidal creeks; common.
Schoenus brevifolius R. Br. Moorlands; common.

Schoenus Tendo Banks & Sol. Moorlands; common.
,, *axillaris* Poir. Swampy places; common.
,, *apogon* Roem. & Schult. Mangonui. T. F. C.
Cladium Sinclairii Hook. f. Sea-cliffs and banks; common.
,, *articulatum* R. Br. Swamps; common.
,, *glomeratum* R. Br. Damp places on moorlands; common.
,, *teretifolium* R. Br. Moorlands; abundant.
,, *Gunnii* Hook. f. Moorlands and open woods; not uncommon.
Cladium junceum R. Br. Brackish-water marshes, abundant; wet moorlands near Kaitaia, common.
Cladium capillaceum C. B. Clarke. Moorlands; not uncommon.
Lepidosperma laterale R. Br. Moorlands; common.
Lepidosperma filiforme Labill. Moorlands, Peria. So far the only known habitat in New Zealand.
Gahnia setifolia Hook. f. Abundant throughout.
,, *pauciflora* T. Kirk. In hilly forests; abundant.
,, *xanthocarpa* Hook. f. In hilly forests; common.
,, *lacera* Steud. In hilly forests; common.
,, *Gaudichaudii* Steud. On dry banks; common.
Uncinia caespitosa Boott. In hilly forests; common.
,, *australis* Pers. Abundant.
Uncinia sp. pps. intermediate between *U. australis* and *U. riparia*. In several places, but not common.
Uncinia leptostachya Raoul. Mangonui. T. F. C.
,, *riparia* R. Br. var. *Banksii* C. B. Clarke. Plentiful.
Carex virgata Sol. Common in swampy places.
,, *secta* Boott. Common in swampy places.
,, *inversa* R. Br. Fairburn; not common.
,, *subdola* Boott. Lowland swamps; common.
,, *ternaria* Forst. Abundant.
,, *dipsacea* Bergg. Flat Bush; rare.
,, *testacea* Sol. On the coast; common.
,, *lucida* Boott. Abundant.
,, *comans* Bergg. On the coast; not common.
,, *dissita* Sol. Typical form; abundant.
,, ,, var. *Lambertiana* Cheesem. Common.
,, ,, var. *ochrosaccus* Cheesem. Abundant.
,, *Solandri* Boott. Ahipara and Mangonui. T. F. C.
,, *breviculmis* R. Br. Plentiful on moorlands.
,, *pumila* Thunb. Plentiful on sand-dunes.
,, *Brownii* Tuckerm. Near Lake Tangonge; rare.
,, *pseudo-cyperus* Linn. Abundant in lowlands.
,, ,, var. *fascicularis*. Common.

Gramineae.

Imperata arundinacea Cyr. var. *Koenigii* Benth. Hillside near Kaitaia.
Zoysia pungens Willd. Abundant on sandy shores.
Paspalum scrobiculatum Linn. Moorlands; common.
Paspalum digitaria Poir. Roadsides, and margins of streams and swamps; abundant and rapidly spreading. Most likely an immigrant.
Paspalum distichum L. Salt marshes and rocks by the sea; common.
Isachne australis R. Br. Plentiful in swamps.

Oplismenus undulatifolius Beauv. Abundant in forests.
Spinifex hirsutus Labill. Abundant on sand-dunes.
Microlaena stipoides R. Br. Abundant in open places.
,, *avenacea* Hook. f. Abundant in forests.
,, *polynoda* Hook. f. Small wood, Tauroa; not common.
Hierochloe redolens R. Br. Not uncommon in swampy places.
Stipa teretifolia Steud. Near the sea; common.
Echinopogon ovatus Beauv. Not uncommon.
Sporobolus indicus R. Br. Abundant. As pointed out in "Manual of the New Zealand Flora," p. 861, this is an immigrant.
Deyeuxia Forsteri Kunth. Abundant in waste places.
,, *Billardieri* Kunth. Near the sea; common.
,, *avenoides* Buch. var. *brachyantha* Hack. Not uncommon.
,, *quadriseta* Benth. Moorlands; common.
Dichelachne crinita Hook. f. Plentiful in open situations.
,, *sciurea* Hook. f. Not common.
Trisetum antarcticum Trin. Mangonui. T. F. C.
Danthonia pilosa R. Br. Abundant.
,, *semiannularis* R. Br. Abundant.
Arundo conspicua Forst. Abundant on sandhills on cost; rare in inland situations.
Arundo fulvida Buch. Creek-banks; common.
Poa anceps Forst. Not uncommon.
,, *seticulmis* Petrie. Sandy places near sea; common.
Festuca littoralis Labill. Sand-dunes; plentiful.
Agropyrum multiflorum T. Kirk. Common on coast.

Filices.

Hymenophyllum rarum R. Br. On tree trunks and branches; common.
Hymenophyllum polyanthos Swartz var. *sanguinolentum* Hook. Abundant in forests.
Hymenophyllum australe Willd. In damp woods; not common.
,, *dilatatum* Swartz. In damp woods; plentiful.
,, *demissum* Swartz. In damp woods; abundant.
,, *scabrum* A. Rich. In damp woods; common.
,, *flabellatum* Lab. In damp woods; common.
Hymenophyllum subtilissimum Kunze. Chiefly on stems of *Dicksonia* and on damp rocks; not uncommon.
Hymenophyllum tunbridgense Smith. In woods; abundant.
,, *multifidum* Swartz. In woods; common.
Trichomanes reniforme Forst. In woods; common.
Trichomanes humile Forst. In woods, on damp rocks; common on stems of *Dicksonia*.
Trichomanes venosum R. Br. In woods; common.
,, *strictum* Menz. Kaitaia; rare.
,, *elongatum* A. Cunn. Damp shaded banks in woods; common.
Loxsoma Cunninghamii R. Br. In woods and on banks of streams; local.
Cyathea dealbata Swartz. Abundant in woods.
,, *medullaris* Swartz. Abundant in woods.
Hemitelia Smithii Hook. Abundant in woods.
Dicksonia squarrosa Swartz. In damp woods; abundant.
,, *lanata* Col. In hilly forests; abundant.

Davallia novae-zealandiae Col. On shaded creek-banks; rare.
Lindsaya linearis Swartz. Moorlands; common.
Lindsaya trichomanoides Hook. f. and var. *Lessonii* Hook. f. Not uncommon in hilly forests.
Adiantum aethiopicum Linn. Plentiful in places, but local.
Adiantum diaphanum Blume. Creek-banks and rocky places in woods; common.
Adiantum hispidulum Swartz. On dry banks; plentiful.
,, *affine* Willd. Abundant.
,, *fulvum* Raoul. In woods; abundant.
Hypolepis tenuifolia Bernh. In damp open situations; abundant.
,, *distans* Hook. Several places in woods; not common.
Cheilanthes Sieberi Kunze. Ahipara; Kaitaia; Mount Camel; maritime rocks.
Pellaea rotundifolia Hook. Usually in damp lowland woods; common.
Pteris aquilina Linn. var. *esculenta* Hook. f. Abundant.
,, *scaberula* A. Rich. Abundant; usually in dry open places.
,, *tremula* R. Br. Abundant in woods.
,, *comans* Forst. Along the coast; not uncommon.
,, *macilenta* A. Rich. In woods; plentiful.
,, ,, var. *pendula* Cheesem. Common.
,, *incisa* Thunb. Abundant.
Lomaria discolor Willd. Abundant in woods.
Lomaria lanceolata Spreng. Creek-banks and damp slopes in woods; abundant.
Lomaria Banksii Hook. Dripping rocks, west coast; rare.
,, *capensis* Willd. Abundant.
,, ,, var. *minor* Hook. f. In kauri bush; not common.
,, *filiformis* A. Cunn. Abundant in woods.
Lomaria nigra Col. In dark ravines between Fairburn and Hokianga; never plentiful.
Lomaria fluviatilis Spreng. Banks of creeks; not uncommon.
,, *membranacea* Col. Banks of streams and shaded slopes; common.
,, *Fraseri* A. Cunn. In hilly forests; abundant.
Doodia media R. Br. On dry banks and slopes; common.
Doodia caudata R. Br. Damp lowlands, Kaitaia; one plant among damp rocks in hilly bush, Fairburn.
Asplenium falcatum Lam. Common in woods; usually pendulous from trees.
,, *obtusatum* Forst. On maritime rocks; not common.
,, *lucidum* Forst. Abundant on trees and rocks.
,, ,, var. *obliquum* Moore. Dry rocks and banks; common.
,, *Hookerianum* Col. Kaitaia; rare and local.
,, *bulbiferum* Forst. Abundant in damp woods.
,, ,, var. *tripinnatum* Hook. f. Not common.
Asplenium flaccidum Forst. Forms pendulous from trees abundant; terrestrial bulbiferous forms much less common.
Asplenium umbrosum J. Sm. Alluvial flats; abundant.
Asplenium japonicum Thunb. Alluvial flats and creek-banks, Fairburn, common; Kaiatia, rarer.
Aspidium Richardii Hook. Not uncommon on rocks, inland and maritime.
,, *capense* Willd. Not uncommon in woods, often climbing up trees.
Nephrodium Thelypteris Desv. var. *squamulosum* Schl. Maritime marshes, not uncommon; swamp, Lake Tangonge.

Nephrodium decompositum R. Br. Damp open situations; common.
Nephrodium glabellum A. Cunn. Fairly dry slopes and creek-banks; common.
Nephrodium velutinum Hook. f. Dry rocky slopes in woods; not uncommon.
Nephrodium hispidum Hook. Plentiful in woods.
Nephrodium unitum R. Br. Maritime marshes, margin of Lake Tangonge; not uncommon.
Nephrodium molle Desv. Near Mangatete; rare.
Polypodium punctatum Thunb. Common.
„ *pennigerum* Forst. Abundant throughout.
„ *australe* Mett. On tree-trunks; common.
„ *grammitidis* R. Br. On tree-trunks; common.
„ *tenellum* Forst. In damp lowland woods; common.
„ *serpens* Forst. On upper branches and rocks; abundant.
Polypodium Cunninghamii Hook. On damp rocks and tree-trunks; common.
Polypodium pustulatum Forst. Abundant in woods.
„ *Billardieri* R. Br. Usually on trees or rocks; abundant.
Gleichenia circinata Swartz. Throughout the district; not common.
„ *dicarpa* R. Br. var. *hecistophylla*. Abundant on wet moorlands.
„ *Cunninghamii* Heward. Plentiful in forests.
„ *flabellata* R. Br. Damp moorlands; not uncommon.
Schizaea fistulosa Labill. Moorlands; common.
„ *bifida* Swartz. Moorlands, Peria; Kaitaia; not common.
„ *dichotoma* Swartz. Kauri forests; common.
Lygodium articulatum A. Rich. In forests; abundant.
Todea barbara Moore. On or near the coast, common; inland, Kaitaia.
„ *hymenophylloides* A. Rich. In damp woods; common.
Marattia fraxinea Smith. In deep gullies of the Maungataniwha Ranges, Herekino; Parapara.
Ophioglossum lusitanicum Linn. Dry sandy places; not common.
Ophioglossum vulgatum Linn. Moist lowland bush and scrub; not uncommon.
Botrychium ternatum Swartz. Not uncommon.
„ *dissectum* Muhl. Rangaunu Heads.

Lycopodiaceae.

Phylloglossum Drummondii Kunze. Barren open places, Kaitaia, and near Rangaunu Harbour.
Lycopodium Billardieri Spring. Usually pendulous from trees, but often terrestrial among *Leptospermum*.
Lycopodium densum Labill. On moorlands among scrub; common.
Lycopodium cernuum L. On moorlands, old land-slips, and roadside cuttings; common.
Lycopodium laterale R. Br. In peaty swamps; common.
Lycopodium Drummondii Spring. Wet peaty swamp near Lake Tangonge; Kaitaia.
Lycopodium volubile Frost. Abundant among scrub.
Tmesipteris tannensis Bernh. Usually on the stems of tree-ferns; common.
Psilotum triquetrum Swartz. Rangaunu Harbour, and at Merita Bay.

Naturalized Plants.

Ranunculus sceleratus Linn.
,, *repens* Linn.
,, *bulbosus* Linn.
,, *sardous* Crantz.
,, *parviflorus* Linn.
,, *muricatus* Linn.
Nasturtium officinale R. Br.
Sisymbrium officinale Scop.
Brassica oleracea Linn.
Capsella Bursa-pastoris D.C. T. F. C.
Senebiera didyma Pers.
,, *coronopus* Poir.
Raphanus sativus L. T. F. C.
Silene gallica L.
Cerastium glomeratum Thuill.
Stellaria media Cyr.
,, *holostea* Linn.
Arenaria serpyllifolia Linn.
Sagina apetala Linn.
Spergula arvensis Linn.
Polycarpon tetraphyllum Linn.
Caladrinia sp.
Portulaca oleracea Linn. T. F. C.
Hypericum perforatum Linn. T. F. C.
,, *humifusum* Linn.
Lavatera arborea Linn.
Malva verticillata Linn.
Modiola mulitfida Moench.
Linum marginale A. Cunn.
,, *gallicum* Linn.
Erodium cicutarium L'Herit.
,, *malachoides* Willd. T. F. C.
Vitis vinifera Linn.
Melianthus major Linn.
Ulex europaeus Linn.
Medicago lupulina Linn. T. F. C.
,, *denticulata* Willd.
-- *maculata* Willd.
Melilotus officinalis Lam. T. F. C.
Trifolium arvense Linn.
pratense Linn.
glomeratum Linn.
hybridum Linn.
repens Linn.
fragiferum Linn.
resupinatum Linn.
procumbens Linn.
Lotus corniculatus Linn.
,, *uliginosus* Schkuhr.
,, *angustissimus* Linn.
Vicia gemella Crantz.
Vicia sativa Linn.
Acacia dealbata Link.
,, *decurrens* Willd.
,, *armata*.
Albizzia lopantha Benth.
Prunus persica Stokes.
Rubus fruticosus Linn.
Fragaria vesca Linn.
Alchemilla arvensis Scop.
Rosa rubiginosa Linn.
,, *multiflora* Thunb.
Eucalyptus globulus Labill. (Blue-gum).
Eucalyptus globulus Labill. (Red-gum.)
Lythrum Hyssopifolia Linn.
Aenothera sp.
Apium graveolens Linn.
,, *leptophyllum* F. Muell.
,, *Lessonii*.
Daucus Carota Linn.
Sambucus niger Linn.
Galium Aparine Linn.
,, *parisiense* Linn.
Sherardia arvensis Linn.
Scabiosa maritima Linn. T. F. C.
Bellis perennis Linn.
Erigeron canadensis L.
,, *linifolius* Willd.
Gnaphalium purpureum Linn.
Achillea millefolium Linn.
Anthemis arvensis Linn.
Chrysanthemum Parthenium Bernh.
,, *leucanthemum* Linn.
Matricaria discoidea D. C.
Soliva anthemifolia R. Br.
Tanacetum vulgare Linn.
Senecio vulgaris Linn.
,, *sylvaticus* Linn.
,, *Jacobaea* Linn.
,, *mikanioides* Otto.
Cnicus lanceolatus Willd.
,, *arvensis* Hoffm.
Cynura cardunculus Linn.
Chicorium Intybus Linn.
Lapsana communis Linn.
Crepis virens Linn.
Hypochaeris radicata Linn.
Leontodon hispidus Linn.
Taraxacum officinale Linn.
Anagallis arvensis L.

Vinca major L.
Erythraea centaurium Pers.
Myosotis collina Hoffm.
Cuscuta epithymum Murr.
foliis. (Dodder.)
Solanum sodomaeum Linn.
Physalis peruviana Linn.
Lycium chinense Mill.
Nicotiana Tabacum Linn.
Verbascum blattaria Linn.
Mimulus sp. (Musk.)
Linaria Elatine Mill.
Veronica agrestis Linn.
,, *arvensis* Linn.
,, *serpyllifolia* Linn.
Bartsia viscosa Linn.
Verbena officinalis Linn.
,, *bonariensis* Linn.
Mentha viridis Linn.
,, *Pulegium* Linn.
Melissa officinalis Linn.
Prunella vulgaris Linn.
Stachys arvensis Linn.
Plantago major Linn.
,, *lanceolata* Linn.
,, *hirtella* H. B. K.
Chenopodium album Linn.
,, *murale* Linn.
Phytolacca octandra Linn.
Polygonum Convolvulus Linn.
Rumex crispus Linn.
,, *sanguineus* Linn. var. *viridis*.
,, *obtusifolius* Linn.
,, *acetosella* Linn.
Hakea acicularis R. Br.
Euphorbia Peplus Linn.
Ricinus communis Linn.
Humulus Lupulus Linn.
Ficus carica Linn.
Salix fragilis Linn.
,, *babylonica* Linn.
Iris germanica Linn.
Antholyza aethiopica Linn.
Agave americana Linn.
Asphodelus fistulosus Linn.
Allium vineale Linn.
Colocasia antiquorum Schott.
Richardia africana Kunth.
Cyperus lucidus R. Br.
Andropogon annulatus Forst. T. F. C.
Paspalum dilatatum Poir.
Panicum sanguinale Linn.
,, *crus-galli* Linn.
Stenotaphrum glabrum Trin.
Phalaris canariensis Linn.
Anthoxanthum odoratum Linn.
Phleum pratense Linn.
Alopecurus pratensis Linn.
Polypogon fugax Nees.
Agrostis vulgaris With.
,, *alba* Linn.
Holcus lanatus Linn.
Aira caryophyllea Linn.
Avena sativa Linn.
,, *strigosa* Schreb.
Cynodon Dactylon Pers.
Eragrostis Brownii Nees.
Briza maxima Linn.
,, *minor* Linn.
Dactylis glomerata Linn.
Cynosurus cristatus Linn.
Poa annua Linn.
,, *pratensis* Linn.
,, *trivialis* Linn.
Festuca elatior Linn.
,, *Myurus* Linn.
Bromus sterilis Linn.
,, *mollis* Linn.
,, *racemosa* Linn.
,, *unioloides* H. B. K.
Lolium perenne Linn.

Art. XXVIII.—*List of Phanerogamic Plants Indigenous in the Wellington Province.*

By B. C. Aston, F.I.C., F.C.S.

[*Read before the Wellington Philosophical Society, 5th October, 1910.*]

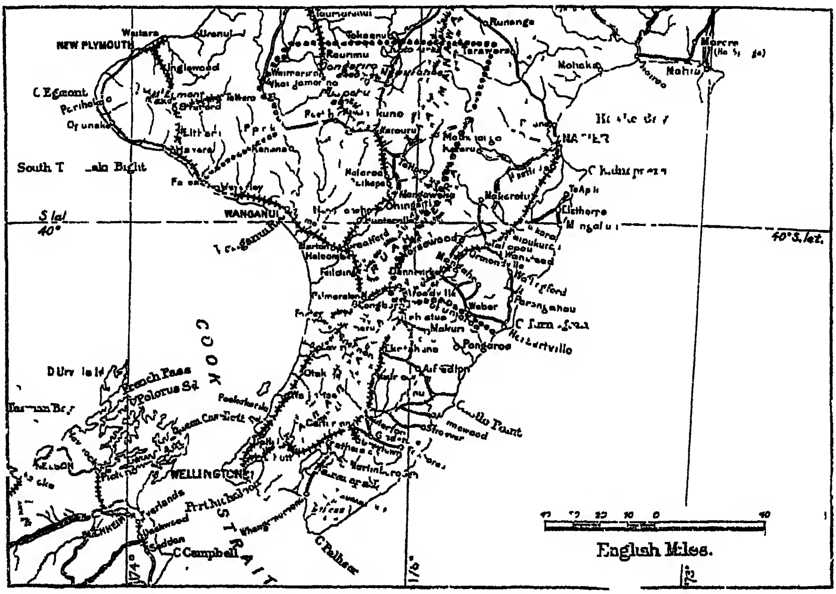
No list of Wellington indigenous flowering-plants has been published since Buchanan (Trans. N.Z. Inst., vol. 6, p. 210), in 1873, published his paper, "Notes on the Flora of the Province of Wellington." In this he gives a list of all indigenous plants known to him, including the cryptogams. In Buchanan's time the flora of the alpine portion of the province was practically unknown, and some of the alpine species included in his list were wrongly identified. Owing to the researches of the late T. Kirk, who from time to time discovered several new species; T. F. Cheeseman ("Manual of the New Zealand Flora," Wellington, 1906), who on three occasions visited the volcanic plateau; D. Petrie ("Visit to Mount Hector," Trans. N.Z. Inst., vol. 40, 1907, p. 289); L. Cockayne ("Report of a Botanical Survey of Tongariro National Park," Lands Department, Wellington, 1908); E. Phillips Turner ("Report of a Botanical Examination of the Higher Waimarino District," Lands Department, Wellington, 1909); and the writer ("Botanical Notes on a Journey across the Tararuas," Trans. N.Z. Inst., vol. 42, 1909, p. 13) the distribution of species has become better known, identifications have been corrected, new species have been described, and the ecology of certain districts has been worked out. Thus, though Buchanan enumerates only 476 species of phanerogams, the present list includes some 680, a fact which alone would warrant the publication of a revised list.

Since this paper was read, the author, with Mr. J. S. Tennant, spent in January, 1911, a week exploring the Kaimanawa Mountains, lying to the south of the volcanic plateau. As a result of this visit it has been found necessary to widen the range in altitude of a number of species. It has, for instance, been quite common to find a plant growing 1,000 ft. above its accepted habitat, a fact which would point to the climate and soil conditions of that range being much more favourable to plant-life than those of mountains of the same altitude elsewhere in the province. The results of the Kaimanawa visit have been largely embodied in this paper.

The land-boundaries of the Wellington Province as defined in a map kindly supplied to me by the Lands Department, Wellington, are as follows: A straight line is drawn from the mouth of the Patea River to Pipiriki, on the Wanganui River, which is the natural boundary from this point to the 39th parallel. Following the parallel eastward, the northern boundary stops at the Ahimanawa Range, a little to the west of the Township of Tarawera. From this point to the Manawatu Gorge the boundary runs south in almost a straight line through the Kaweka Range, but following at the southern end the axis of the Ruahine Range. From the Gorge the

boundary follows the Manawatu River eastward to its southernmost point, and then strikes off to the coast at the mouth of the Waimata River. Wellington Province consists of the country lying from the south of the boundary to the coast.

The author has made full use of the information contained in the works of Cheeseman, Petrie, Cockayne, and Turner. Where a habitat has not been verified by the author the authority for its insertion has been given. For the rarer plants the actual habitat has been given. For those less common the type of country or altitude it inhabits is recorded. For the commonest merely the names and dates of flowering are stated. The names of the months refer to the dates of flowering, which have generally been verified by the author. The term "volcanoes" refers to the volcanic



MAP OF SOUTHERN PART OF NORTH ISLAND.

(Dotted line shows the boundary of Wellington District.)

plateau, including Ruapehu (9,175 ft.), Tongariro (6,458 ft.), and Ngauruhoe (7,515 ft.). In deference to the wishes of the Publication Committee, the trivial and Maori names of species have been omitted.

Finality in any respect is, of course, impossible. The author merely wishes to place on record what is known of a flora which even in the so-called reserves is rapidly changing through the attacks of wild rabbits, pigs, horses, and cattle. It is hoped at some future date, when the northern and eastern portions of the province have been more fully explored, to correlate in some degree the quality of the soil with the quality of the flora.

The author desires to thank Dr. D. Petrie and Mr. T. F. Cheeseman for their many kindnesses, especially in identifying plants and supplying dried specimens from their herbaria, and for much valuable information.

LIST OF PHANEROGAMIC PLANTS INDIGENOUS IN THE WELLINGTON PROVINCE.

1. Ranunculaceae.

Clematis indivisa Willd. Aug.–Nov. Ascends to 2,500 ft.
hexasepala D. C. Sept.–Nov. Marton.
Colensoi Hook. f. Nov.-Jan. On dry hillsides. Ascends to 3,000 ft.
parviflora A. Cunn. Oct.-Nov. Ascends to 1,500 ft.
marata Armst. Sept.-Nov. Near Wanganui (Allison).
Myosurus aristatus Benth. Palliser Bay (Col.); ocean-beach, Wellington (Buch.).
Ranunculus insignis Hook. f. Dec.–Jan. Volcanoes; Tararua and Ruahine Mountains. 4,000–5,000 ft.
Monroi Hook. f. Dec.–Jan. Tararua Mountains (Buch.).
nivicola Hook. Dec.–Feb. Volcanoes; Kaimanawa Mountains. 3,000–6,000 ft.
geraniifolius Hook. f. Oct.–Dec. Ruapehu and Tararua Mountains; Tongariro (T. F. C.); Hauhangatahi (Spencer). 2,000–5,500 ft.
tenuicaulis Cheesem. Mount Holdsworth (Cock.).
hirtus Banks & Sol. Oct.–Jan. Ascending to 4,000 ft.
recens T. K. Levin Beach. Coastal.
lappaceus Smith. Nov.–Mar. Ascending to 4,500 ft.
macropus Hook. f. Dec.–Jan. Wainuiomata (Buch.).
rivularis Banks & Sol. Oct.–Mar. In swamps and creeks. Ascends to 4,000 ft. in Kaimanawa Mountains and volcanoes.
acaulis Banks & Sol. Sept.–Nov. Coastal.
Caltha novae-zealandiae Hook. f. Oct.–Jan. Ruahine and Tararua Mountains. 2,500–5,500 ft.

2. Magnoliaceae.

Drimys axillaris Forst. Oct.–Dec. Ascending to 3,500 ft. on Kaimanawas.
colorata Raoul. Nov.–Dec. Ascending to 4,000 ft. on volcanoes.

3. Cruciferae.

Nasturtium palustre D. C. Nov.–Dec. Upper Wairarapa (Buch.).
Cardamine hirsuta Linn. Flowers throughout the year. Ascending to 5,000 ft.
Lepidium oleraceum Forst. Near Terawhiti, and sparingly round the coast.
obtusatum T. K. Oct.–Feb. Port Nicholson (T. K.).
tenuicaule T. K. var. *minor* Cheesem. Nov.–Jan. Titahi Bay.

4. Violaceae.

Viola filicaulis Hook. f. Nov.–Feb. Ascending to 4,000 ft.
Lyallii Hook. f. Oct.–Jan. Ascending to 4,000 ft.
Cunninghamii Hook. f. Oct.–Jan. Ascending to 5,000 ft.
Melicytus ramiflorus Forst. Oct.–April. Ascending to 3,000 ft.
lanceolatus Hook. f. Tararua Mountains. Ascending to 2,600 ft. a Waimarino.
micranthus Hook. f. Dec.–Feb. Upper Wairarapa (Buch.).
Hymenanthera crassifolia Hook. f. July–Aug. Bluffs on Onetapu Desert, 3,500 ft.; base of Ruapehu. Usually coastal.
dentata R. Br. var. *angustifolia* Benth. Upper Rangitikei (Petrie); Turangaarere (Hamilton); volcanoes, 4,300 ft. (Cheesem.).
obovata T. K. Nov. Titahi Bay. Considered by Cheeseman to be intermediate between *H. crassifolia* and *H. obovata*.
chathamica T. K. Sept.–Oct. Patea (Hector).

5. Pittosporaceae.

Pittosporum tenuifolium Banks & Sol. Oct.–Nov. Ascending to 3,000 ft.
Colensoi Hook. f. Oct.–Nov. Upper Rangitikei (Buch.); base of Tongariro, Waimarino Forest (T. F. C.). Ascends to 3,500 ft. on Kaimanawas.
Buchanani Hook. f. Wellington (T. K.).
rigidum Hook. f. Dec. Ruahine and Tararua Mountains, 3,500–4,000 ft.; volcanoes (Cock.).
Ralphii T. K. Oct.–Nov. Upper Wanganui (Field); Patea (T. K.).
Kirkii Hook. f. Dec.–Jan. Ohakune, at 2,000 ft. (Turner).
cornifolium A. Cunn. June–Sept. Epiphytic. Ascending to 2,800 ft.
eugenioides A. Cunn. Sept.–Oct. Ascending to 1,000 ft. at Waimarino.

6. Caryophyllaceae.

Gypsophila tubulosa Boiss. Cape Palliser (Col.).
Stellaria parviflora Banks & Sol. Ascending to 4,000 ft.
Colobanthus Billardieri Fenzl. Ruahine, Kaimanawa, and Tararua Mountains. Ascends to 4,500 ft.
Muelleri T. K. Usually coastal.
Spergularia media Presl. Oct.–Feb. Coastal.

7. Portulacaceae.

Claytonia australasica Hook. f. Ruahine, volcanoes; Kaimanawa and Tararua Mountains. Ascending to 6,500 ft. (T. F. C.).
Montia fontana Linn. Ascending to 4,000 ft.

8. Elatinaceae.

Elatine americana Arn. var. *australiensis* (Benth.). Muddy places and margins of still waters.

9. Hypericaceae.

Hypericum gramineum Forst. Ascending to 2,000 ft.
japonicum Thunb. Ascending to 3,000 ft.

10. Malvaceae.

Plagianthus divaricatus Forst. Sept.–Oct. Salt marshes.
betulinus A. Cunn. Nov.–Dec. Ascending to 2,500 ft. at Waimarino.
Hoheria populnea A. Cunn. Dec.–Feb. Ascending to 2,200 ft. at Waimarino.

11. Tiliaceae.

Entelea arborescens R. Br. Nov. Cape Palliser and Paekakariki (T. K.).
Aristotelia racemosa Hook. f. Sept.–Dec. Fruit, January. Ascending to 3,000 ft. on Kaimanawa Mountains.
Colensoi Hook. f. Wairarapa Valley (Col.). Ascending to 2,600 ft. at Waimarino (Turner).
fruticosa Hook. f. Ascends to 4,000 ft.
Elaeocarpus dentatus Vahl. Oct.–Nov. Ascending to 2,600 ft. at Pokaka (Turner).
Hookerianus Raoul. Nov.–Jan. Ascending to 3,500 ft.

12. Linaceae.

Linum monogynum Forst. Oct.–Jan.

13. Geraniaceae.

Geranium dissectum Linn. var. *australe* Benth. Dec.–Mar.
microphyllum Hook. f. Dec. Ascends to 3,000 ft.
sessiliflorum Cav. Nov.–Dec. Ascends to 3,000 ft.
molle Linn. Nov.–Feb.
Pelargonium australe Jacq. Nov.–Feb. Ascending to 2,000 ft.
Oxalis corniculata Linn. Flowers summer months.
magellanica Forst. Nov.–Dec. Ascends to 4,000 ft.

14. Rutaceae.

Melicope ternata Forst. Sept.–Oct.
ternata var. *Mantellii* Kirk. Little Mukumuku.
simplex A. Cunn. Sept.–Nov. Ascending to 3,000 ft. on Tongariro.

15. Meliaceae.

Dysoxylum spectabile Hook. f. April–July.

16. Olacinaceae.

Pennantia corymbosa Forst. Nov.–Dec. Ascending to 2,600 ft. at Pokaka (Turner).

17. Stackhausiaceae.

Stackhausia minima Hook. f. Dec.–Jan. Waimarino, 2,700 ft. (Phillips Turner); volcanoes, 3,500 ft. (Cock., T. F. C.).

18. Rhamnaceae.

Pomaderris phylicaefolia Lodd. Oct.–Jan. Pongaroa; Cape Palliser; Otaki.
Discaria toumatou Raoul. Oct.–Dec.

19. Sapindaceae.

Dodonea viscosa Jacq. Nov.–Dec.
Alectryon excelsum Gaertn. Nov.–Dec.

20. Anacardiaceae.

Corynocarpus laevigata Forst. Sept.–Nov. Fruit, February.

21. Coriariaceae.

Coriaria ruscifolia Linn. Oct.–Dec. Ascending to 3,500 ft.
thymifolia Humb. & Bonp. Ascending to 5,000 ft.
angustissima Hook. f. Dec.–Jan. 1,500–4,000 ft. Ascends to 4,500 ft. on Kaimanawa Mountains.

22. Leguminosae.

Carmichaelia Enysii T. K. Dec.–Jan. Ruapehu (T. K.). 1,500–3,000 ft.
nana Col. Ruapehu. Ascends to 2,800 ft.
odorata Col. Nov.–Jan. River-gorges of Ruahine and Tararua Mountains. Ascending to 2,500 ft.
flagelliformis Col. Nov.–Jan. Ascending to 4,000 ft. on Kaimanawas and volcanoes (T. F. C.).
Sophora tetraptera J. Mull. Aug.–Oct. Ascends to 800 ft. at Kakahi (Turner).

23. Rosaceae.

Rubus australis Forst. Sept.–Oct. Ascends to 4,000 ft. on Kaimanawa Mountains.
cissoides A. Cunn. Sept.-Nov. Ascends to 2,600 ft. at Waimarino.
schmidelioides A. Cunn. Oct.-Nov. Ascends to 2,600 ft. at Waimarino.
Geum urbanum Linn. var. *strictum*. Nov. Jan. Upper Wairarapa (Buch.). Ascending to 3,000 ft.
parviflorum Sm. Dec.- Feb. Ruahine and Tararua Mountains. 4,000–5,000 ft.
Potentilla anserina Linn. Dec.–Jan.
Acaena novae-zealandiae T. K. Nov.–Jan.
Sanguisorbae Vahl. Nov.–Feb. Ascends to 3,500 ft.
microphylla Hook. f. Nov.–Jan. Ascends to 3,500 ft.

24. Saxifragaceae.

Donatia novae-zealandiae Hook. f. Dec.–Mar. 4,000–5,000 ft., Mount Holdsworth (Townson).
Carpodetus serratus Forst. Nov.–Jan. Ascending to 3,000 ft.
Weinmannia racemosa Linn. f. Dec.–Jan. Ascending to 3,000 ft.

25. Crassulaceae.

Tillaea moschata D. C. Coastal.
diffusa T. K. Miramar (T. K.); near Seatoun. Coastal.
Sieberiana Schultz. Sept.–Jan.
debilis Col. Happy Valley Beach; Quoin, 1,000 ft.
purpurata Hook. f. Cape Palliser (Col.).

26. Droseraceae.

Drosera stenopetala Hook. f. Dec.–Feb. Ruahine and Tararua Mountains. 2,500–5,000 ft.
Arcturi Hook. f. Ruahine Mountains (Col.); Kaimanawa Mountains. 2,000–5,000 ft.
spatulata Labill. Nov.–Feb. Volcanoes and Kaimanawa Mountains. Ascending to 5,000 ft.
binata Labill. Nov.–Feb. Ascends to 2,500 ft.
auriculata Backh. Oct.–Jan. Ascending to 2,500 ft.

27. Haloragidaceae.

Haloragis alata Jacq. Nov.–Jan. Ascending to 2,000 ft.
tetragyna Hook. f.
depressa Walp. Ascending to 2,600 ft. at Pokaka.
micrantha R. Br. Ascending to 4,500 ft. on Kaimanawa Mountains and volcanoes.
Myriophyllum elatinoides Gaud. Nov.–Feb. Ascending to 3,500 ft.
intermedium D. C. Dec.–Mar. Ascending to 3,500 ft.
pedunculatum Hook. f. Dec.–Feb. Ascending to 3,000 ft.
robustum Hook. f. Dec.–Feb. Ascends to 2,000 ft., Mungaroa (T. K.).
Gunnera monoica Raoul. Nov.–Jan. Ascends to 3,500 ft.
prorepens Hook. f. Upper Wairarapa (Buch.); volcanoes (Cock.).
dentata T. K. Dec.–Feb. Taupo (D. P.).
arenaria Cheesem. Levin Beach; Waikanae to Patea (Cock.). Coastal.
Callitriche verna Linn. Aquatic.

28. Myrtaceae.

Leptospermum scoparium Forst. Oct.–April. Ascending to 5,000 ft. on Kaimanawa Mountains.
  ericoides A. Rich. Nov.–Dec. Ascending to 3,000 ft.
Metrosideros florida Sm. Feb.–June. Ascending to 2,500 ft.
  lucida A. Rich. Dec.–Jan. Ascending to 3,500 ft.
  hypericifolia A. Cunn. Nov.–Jan. Ascending to 2,000 ft.
  Colensoi Hook. f. Dec.–Jan. Ascends to 2,000 ft. at Ohakune (Turner).
  robusta A. Cunn. Dec.–Jan. Ascends to 3,000 ft.
  scandens Sol. Jan.–Mar. Ascends to 2,000 ft.
Myrtus bullata Sol. Dec.–Jan. Ascends to 2,000 ft.
  Ralphii Hook. f. Dec.–Jan. Ascends to 1,500 ft.
  obcordata Hook. f. Dec.–Jan. Ascending to 2,000 ft.
  pedunculata Hook. f. Dec.–Jan. Ascends to 3,500 ft. on Kaimanawa Mountains.
Eugenia maire A. Cunn. Mar.–May. Fruit, Jan.–Feb. Ascending to 1,500 ft.

29. Onagraceae.

Epilobium pallidiflorum Sol. Nov.–Feb. Ascending to 2,600 ft. at Pokaka (Turner).
  chionanthum Haussk. Nov.–Feb. Ascending to 1,500 ft.
  Billardieranum Ser. Nov.–Feb. Ascending to 2,000 ft.
  erectum Petrie. Dec.–Jan. Ascends to 3,500 ft. on Kaimanawas.
  junceum Sol. Oct.–Feb. Ascending to 3,500 ft.
  pubens A. Rich. Oct.–Jan. Ascending to 4,000 ft.
  tenuipes Hook. f. Dec.–Jan. Mount Holdsworth (Cock.); Wairarapa Valley (Col.); Ruahine Mountains (Hamilton). Ascends to 3,500 ft. on Kaimanawas.
  Hectori Haussk. Dec.–Feb. Ruahine Mountains (Col.).
  Cockaynianum Petrie. Tararua Mountains. 3,300–4,500 ft.
  alsinoides A. Cunn. Nov.–Feb. Ascending to 3,000 ft. on volcanic plateau.
  chloraefolium Haussk. Dec.–Feb. Ruahine (Col., D. P.); Kaimanawa and Tararua Mountains. Ascends to 4,500 ft.
  insulare Haussk. Nov.–Feb. Ascending to 1,000 ft. at Waimarino (Turner).
  rotundifolium Forst. Oct.–Feb. Ascends to 3,500 ft. at Kaimanawa Mountains.
  linnaeoides Hook. f. Nov.–Feb. Ruahine Mountains (Col.); Tararua Mountains (Buch.). Ascends to 4,500 ft.
  nummularifolium R. Cunn. Jan. Ascends to 3,500 ft. on Kaimanawa Mountains.
  macropus Hook. Dec.–Mar. 1,500–4,500 ft., Ruahine (Petrie, Andrews); Kaimanawa and Tararua Mountains (Buch.); volcanoes (Cock.).
  gracilipes T. K. Dec.–Feb. Tararua Mountains (D. P.); Ruahine Mountains (Col.).
  melanocaulon Hook. Ruahine Mountains (Col.); Tauherenikau Valley; Kaimanawa Mountains, 3,000 ft.
  microphyllum A. Rich. Dec.–Feb. Cape Palliser (Col.); Orongorongo River (T. K.); Kaimanawa Mountains. Ascending to 3,000 ft.
  glabellum Forst. Dec.–Feb. Ascends to 5,000 ft.
  glabellum var. *erubescens*. Tongariro, 5,500 ft. (T. F. C.).

Fuchsia excorticata Linn. f. Aug.–Dec. Fruit, January. Ascends to 3,500 ft. on Kaimanawas.
Colensoi Hook. f. Oct.–Feb. Ascends to 1,500 ft.

30. Passifloraceae.

Passiflora tetrandra Banks & Sol. Nov.–Jan. Ascending to 2,500 ft.

32. Ficoidaceae.

Mesembryanthemum australe Sol. Oct.-Mar. Coastal.
aequilaterale Haw. Dec.-Feb. Castlepoint (T. K.).
Tetragonia trigyna Banks & Sol. Oct.–Feb. Coastal.

33. Umbelliferae.

Hydrocotyle elongata A. Cunn. Nov.-Mar. Ascending to 2,000 ft.
tripartita R. Br. Tongariro (Col. and Cock.).
americana Linn. Oct.–Feb. Ascending to 2,000 ft.
novae-zealandiae D. C. Nov.-Mar. Ascending to 4,000 ft.
moschata Forst. Nov.–Mar. Ascending to 2,000 ft.
microphylla A. Cunn. Dec.-Feb.
asiatica Linn. Oct.–Mar. Ascending to 3,500 ft.
Azorella Haastii Benth. & Hook. Dec.–Feb. Ruahine Mountains (Hamilton). 2,000–5,000 ft.
Hookeri Drude. Nov.-Feb. Ascends to 3,500 ft. on Kaimanawas.
Eryngium vesiculosum Lab. Jan. Coastal.
Apium prostratum Lab. Nov.–Mar. Coastal.
Oreomyrrhis andicola Endl. Nov.–Feb. Ascending to 5,000 ft. on volcanoes (T. F. C.).
Crantzia lineata Nutt. Nov.–Feb. Ascends to 2,500 ft.
Aciphylla Colensoi Hook. f. Dec.–Jan. Ruahine (Howlett); Kaimanawa and Tararua Mountains. Ascending to 5,000 ft.
squarrosa Forst. Oct.–Jan. Ascends to 3,500 ft.
Munroi Hook. f. Dec.–Jan. Mount Holdsworth (D. P.). 4,000 ft.
n.s. Occurs on Quoin, Hector, Holdsworth, and Dundas. 3,500–4,000 ft.
Ligusticum dissectum T. K. Dec.-Feb. Tararuas. 3,500-4,000 ft.
aromaticum Hook. f. Nov.–Feb. 1,500 7,000 ft. on Ruapehu (Cock., T. F. C.).
Angelica Gingidium Hook. f. Nov.-Jan. Rare. Ascends to 4,000 ft. Waiouru Plain.
geniculata Hook. f. Jan.–Feb. Wellington: on dry hillside near sea, Paekakariki (H. B. Kirk).
rosaefolia Hook. Oct.–Nov. Ruahine Mountains (Harding); Upper Rangitikei (Buch.).
Daucus brachiatus Sieb. Oct.–Dec.

34. Araliaceae.

Panax simplex Forst. Nov.–Jan. Ascends to 4,000 ft.
Edgerleyi Hook. f. Jan.–Feb. Ascends to 2,500 ft.
anomalum Hook. Dec.–Feb. Ascends to 3,500 ft. on Kaimanawa Mountains.
Sinclairii Hook. f. Jan.–Feb. Ruahine Mountains (Col.); Karioi Mountains (T. F. C.); Kaimanawa Mountains. 1,000–3,500 ft.
Colensoi Hook. f. Dec.–Feb. 1,800–4,500 ft.
arboreum Forst. June–July. Ascends to 1,500 ft.

Schefflera digitata Forst. Feb.–Mar. Ascends to 3,000 ft.
Pseudopanax crassifolium Koch. Feb.–April. Ascends to 2,600 ft. at Pokaka (Turner).

35. Cornaceae.

Corokia Cotoneaster Raoul. Nov.–Jan. Ascends to 3,000 ft. on Kaimanawa Mountains; Upper Wairarapa; Taihape (P. T.); Wanganui (Cock.).
Griselinia lucida Forst. Oct.–Nov.
littoralis Raoul. Oct.–Nov. Ascends to 3,500 ft.

36. Caprifoliaceae.

Alseuosmia macrophylla A. Cunn. Sept.–Nov. Tararua Mountains (D. P.). Ascends to 3,000 ft.
quercifolia A. Cunn. Sept.–Nov. Waimarino (Turner).

37. Rubiaceae.

Coprosma grandifolia Hook. f. April–June. Ascends to 2,500 ft.
lucida Forst. Sept.–Nov. Ascends to 3,200 ft.
Baueri Endl. Sept.–Nov. Coastal.
robusta Raoul. Aug.–Oct. Ascends to 2,500 ft.
Cunninghamii Hook. f. Aug.–Sept. Ascends to 1,000 ft. at Waimarino (Turner).
tenuifolia Cheesem. Aug.–Sept. Kaimanawa and Ruahine Mountains (Col.); Upper Wanganui and Rangitikei Valleys (T. K.); volcanoes (Cock.); Upper Wanganui River (T. F. C.). 1,000–4,000 ft.
rotundifolia A. Cunn. Sept.–Oct. Ascends to 2,000 ft.
areolata Cheesem. Sept.–Oct. Fruit, January. Ascends to 1,500 ft.
tenuicaulis Hook. f. Sept.–Oct. (Buch.). Ascends to 1,000 ft.
rhamnoides A. Cunn. Aug.–Oct. Ascends to 3,000 ft.
parviflora Hook. f. Oct.–Jan. Ascends to 4,500 ft. on Kaimanawas.
ramulosa Petrie. Mount Hikurangi (D. P.); Mount Holdsworth. 2,500–5,000 ft.
Buchanani T. K. Oct. Tongue Point; Happy Valley Bay. Coastal.
crassifolia Col. Sept.–Nov. Ascends to 1,200 ft.
rigida Cheesem. Sept.–Oct.
rubra Petrie. Sept.–Nov. Maungatiriri River; foot of Mount Holdsworth (D. P.).
virescens Petrie. Sept.–Oct. Wairarapa (Col.). Ascends to 1,500 ft.
acerosa A. Cunn. Sept.–Nov. Ascending to 4,000 ft.
propinqua A. Cunn. Sept.–Oct. Fruit, April.
Kirkii Cheesem. Coastal, near Maranui.
linariifolia Hook. f. Kaimanawa Mountains. 3,000 ft.
foetidissima Forst. Aug.–Oct. Ascends to 4,500 ft.
Colensoi Hook. f. Nov.–Jan. Tararua and Kaimanawa Mountains. 1,000–3,500 ft.
cuneata Hook. f. Tararua, Kaimanawa, and Ruahine Mountains (Col.). 2,000–5,000 ft.
microcarpa Hook. f. Tararua, Kaimanawa (ascending to 3,500 ft.), and Ruahine Mountains; Day's Bay; volcanoes; Kakaramea to Waimarino (T. F. C.).
depressa Col. Dec.–Jan. Ruahine Mountains (Col.); Kaimanawa Mountains (Cock.); volcanoes. 2,500–5,000 ft.
repens Hook. f. Dec.–Jan. Tararua Mountains. Ascends to 6,500 ft. on volcanoes (T. F. C.).
Petriei Cheesem. Nov.–Jan. Volcanoes (Cock.). Ascends to 4,000 ft.

Nertera depressa Banks & Sol. Oct.–Jan. Ruahine Mountains (Col.); volcanoes (T. F. C.). Ascends to 4,000 ft.
Cunninghamii Hook. f. Oct.–Jan. Cook Strait (Cheesem.).
dichondraefolia Hook. f. Oct.–Dec. Ascends to 3,000 ft.
setulosa Hook. f. Nov.–Jan. Wairarapa (Buch.); Wellington (T. K.); Tongariro (Cock.).
Galium tenuicaule A. Cunn. Dec.–Mar. Ascends to 2,500 ft.
umbrosum Sol. Dec.–Mar. Ascends to 3,000 ft.
Asperula perpusilla Hook. f. Nov.–Jan. Ascends to 3,000 ft.

38. Compositae.

Lagenophera Forsteri D. C. Oct.–Feb. Ascends to 3,000 ft.
petiolata Hook. f. Nov.–Jan. Ascends to 4,000 ft.
Brachycome Sinclairii Hook. f. Nov.–Jan. Ascends to 4,000 ft.
odorata Hook. f. Inland Patea (Col.).
Olearia Colensoi Hook. f. Dec.–Jan. Ruahine and Tararua Mountains; Mount Matthews (Travers). 3,000–5,000 ft.
nitida Hook. f. Nov.–Jan. Ascends to 4,000 ft.
macrodonta Baker. Jan.–Feb. 1,500–4,000 ft.
ilicifolia Hook. f. Jan.–Feb. Ascends to 4,000 ft.
Cunninghamii Hook. f. Oct.–Dec. Ascends to 2,500 ft.
excorticata Buch. Dec.–Jan. Tararua Mountains. 3,700–4,200 ft.
lacunosa Hook. f. Dec.–Jan. Tararua Mountains. 3,700–4,200 ft.
alpina Buch. Dec.–Jan. Tararua Mountains. 3,700–4,200 ft. (A variety of the preceding species, Petrie).
nummularifolia Hook. f. Volcanoes and Kaimanawa Mountains. 2,000–5,000 ft.
Forsteri Hook. f. April–May. Ascends to 1,500 ft.
virgata Hook. f. Dec.–Jan. Feilding; volcanoes (Cock., Turner). Ascends to 3,000 ft.
Solandri Hook. f. Feb.–May. Ascends to 1,000 ft.
Celmisia incana Hook. f. Dec.–Jan. Tararua Mountains (Buch.); Ruahine Mountains (Col.); Waimarino (P. T.); volcanoes (T. F. C.). 2,000–5,000 ft.
spectabilis Hook. f. Dec.–Feb. Tararua and Kaimanawa Mountains; volcanoes (T. F. C.). 2,000–5,000 ft.
coriacea Hook. f. Dec.–Feb. Tararua Mountains (Buch.). 1,500–4,500 ft. (This needs confirmation, as every recent botanist notes.)
longifolia Cass. Nov.–Jan. Ascends to 5,000 ft.
Hectori Hook. f. Jan.–Feb. Tararua Mountains (Budden). 4,500–5,000 ft.
glandulosa Hook. f. Dec.–Jan. Upper Rangitikei (Buch.); Kaimanawa Mountains; volcanoes. 1,500–4,500 ft.
Vittadinia australis A. Rich. Nov.–Jan. Ascends to 3,000 ft.
Gnaphalium Lyallii Hook. f. Nov.–Jan. Ruahine Mountains (Col.); Rimutaka Mountains (T. K.). Ascends to 2,500 ft.
trinerve Forst. Nov.–Dec. Rimutaka Mountains (T. K.). Ascends to 2,000 ft.
Keriense A. Cunn. Oct.–Dec. Ascends to 3,500 ft. on Kaimanawa Mountains.
subrigidum Col. Oct.–Dec. Makuri Gorge; Wanganui Ascends to 2,000 ft.

Gnaphalium Traversii Hook. f. Dec.–Feb. Tararua Mountains. 1,500–5,000 ft.
paludosum Petrie. Dec.–Jan. Ruahine Mountains (Petrie); volcanoes (T. F. C., Hill). Ascends to 4,700 ft. on Kaimanawas.
luteo-album Linn. Nov.–Mar. Ascends to 3,500 ft. on Kaimanawa Mountains.
japonicum Thunb. Nov.–Jan. Ascends to 3,500 ft. on Kaimanawa Mountains.
collinum Labill. Nov.–Mar. Ascends to 4,500 ft.
Raoulia australis Hook. f. Oct.–Jan. Ascends to 5,500 ft.
tenuicaulis Hook. f. Dec.–Jan. Rimutaka and Kaimanawa Mountains. Ascends to 5,000 ft.
glabra Hook. f. Dec.–Jan. Rimutaka and Tararua Mountains. Ascends to 4.000 ft.
grandiflora Hook. f. Dec.–Jan. 3,000–6,500 ft. All mountains, but not common on Kaimanawas.
rubra Buch. Jan. Tararua Mountains. 4,200–5,200 ft.
Helichrysum bellidioides Willd. Nov.–Feb. Ascends to 7,500 ft. on Ruapehu (Cock., T. F. C.).
filicaule Hook. f. Dec.–Feb. Ascends to 4.000 ft.
fasciculatum Buch. Tararua Mountains (Travers). 4,000–5,000 ft.
Logani T. K. Jan. Mount Holdsworth and Mount Hector; Tararua Mountains. 4,000–4,500 ft.
Leontopodium Hook. f. Jan.–Feb. Ruahine (Col.); Tararua and Kaimanawa Mountains; Ruapehu (scarce, T. F. C.); Hauhangatahi (Spencer). 4,000–5,200 ft.
glomeratum Benth. & Hook. f. Oct.–Jan. Ascends to 3,000 ft. on Kaimanawa Mountains.
Cassinia leptophylla R. Br. Dec.–Feb.
Vauvilliersii Hook. f. Dec.–Jan. Ascends to 5,000 ft. on Kaimanawa Mountains.
fulvida Hook. f. Dec.–Feb. (Buch.). Ascends to 3,500 ft.
Craspedia uniflora, Forst. Dec.–Feb. Ascends to 5,000 ft.
Cotula coronopifolia Linn. Oct.–Feb. In wet places.
australis Hook. f. Sept.–Mar.
minor Hook. f. Nov.–Jan. ? Titahi Bay (identification uncertain, Petrie). Ascends to 2,500 ft.
pyrethrifolia Hook. f. Dec.–Feb. Mount Hector. 5,000 ft.
perpusilla Hook. f. Nov.–Feb. (Buch.). ? Kapiti Island (Cock.). Ascends to 4.500 ft.
dioica Hook. f. Nov.–Feb. Ascends to 3,000 ft.
Centipeda orbicularis Lour. Jan.–Mar. Ascends to 2,000 ft.
Abrotanella pusilla Hook. f. Ruahine Mountains (Col.); Tararua Mountains. 3,900–5,000 ft.
Erechtites prenanthoides D. C. Oct.–Jan. Ascends to 3,000 ft.
arguta D. C. Nov.–Feb. Ascends to 2,500 ft.
scaberula Hook. f. Nov.–Feb. Ascends to 1,500 ft.
quadridentata D. C. Nov.–Feb. Ascends to 3,500 ft.
diversifolia Petrie. Dec.–Jan. Base of Ruapehu (D. P.). Ascends to 3,000 ft.
glabrescens T. K. Jan.–Feb. Upper Rangitikei (D. P.); Tongariro (Cock.). Ascends to 4,500 ft.
Brachyglottis rapanda Forst. Aug.–Oct. Ascends to 3,000 ft. on Kaimanawas.
rangiora Buch. July–Sept. Shores of Cook Strait (Buch. and T. K.).

Senecio lagopus Raoul. Nov.–Jan. Ascends to 4,500 ft.
lautus Forst. Oct.–Nov. Ascends to 4,500 ft.
Turneri Cheesem. Nov.–Dec. Wanganui River, near Pipiriki.
latifolius Banks & Sol. Nov.–Feb. Abundant in Makuri Gorge. Ascends to 3,500 ft. on Kaimanawas.
Kirkii Hook. f. Oct.–Dec. Ascends to 2,500 ft.
Greyii Hook. f. Jan. On cliff-faces, Palliser Bay. Ascends to 1,500 ft.
compactus T. K. Jan.–Feb. Castlepoint (T. K.).
Adamsii Cheesem. Jan.–Feb. Mount Holdsworth, 4,000 ft.
elaeagnifolius Hook. f. Dec.–Feb. Ascends to 4,500 ft.
Bidwillii Hook. f. Dec.–Jan. 2,500–5,500 ft.
Microseris Forsteri Hook. f. Dec.–Feb. Ascends to 4,000 ft.
Taraxacum officinale Wigg. Nov.–Feb. Ascends to 4,000 ft.
Sonchus asper Hill. Spring to autumn.
oleraceus Linn.

39. Stylidiaceae.

Phyllachne Colensoi Bergg. Dec.–Feb. 3,000–6,000 ft.
Oreostylidium subulatum Bergg. Dec.–Mar. Ruahine Mountains (Pryor); base of Tongariro (Kirk). Ascends to 6,000 ft.
Forstera Bidwillii Hook. f. Dec.–Mar. 2,500–6,000 ft.
tenella Hook. f. Dec.–Mar. 1,500–4,500 ft.

40. Goodeniaceae.

Selliera radicans Cav. Nov.–Jan. Ascends to 3,500 ft. on Kaimanawas.

41. Campanulaceae.

Pratia angulata Hook. f. Nov.–Feb. Ascends to 4,500 ft.
perpusilla Hook. f. Nov.–Jan. Between Rangitikei and Turakina Rivers (Cock.).
Lobelia anceps Linn. f. Nov.–Mar.
Wahlenbergia gracilis A. D.C. Nov.–Feb. Ascends to 6,000 ft.
saxicola A. D.C. Dec.–Feb. Ascends to 6,000 ft.

42. Ericaceae.

Gaultheria antipoda Forst. Ascends to 6,000 ft.
perplexa T. K. Otaki. Ascends to 5,000 ft. on Kaimanawa Mountains.
rupestris R. Br. Nov.–Feb. Ascends to 7,000 ft. on Ruapehu (Cock.).
fagifolia Hook. f. Jan. Waimarino (Turner). 1,000–2,000 ft.
oppositifolia Hook. f. Nov.–Jan. Near Wanganui (Field). 500–3,500 ft.

43. Epacridaceae.

Pentachondra pumila R. Br. Dec.–Feb. 2,000–5,000 ft.
Cyathodes acerosa R. Br. Aug.–Nov. Ascends to 4,000 ft. on Kaimanawas.
empetrifolia Hook. f. Nov.–Jan. Ascends to 4,500 ft.
Colensoi Hook. f. Dec.–Jan. Volcanoes, Ruahine (Col.); Tararua and Kaimanawa Mountains. 2,000–5,000 ft.
pumila Hook. f. Tararua Mountains. 2,500–5,000 ft.
Leucopogon fasciculatus A. Rich. Sept.–Nov. Ascends to 3,500 ft.
Fraseri A. Cunn. Sept.–Jan. Ascends to 4,500 ft.
Epacris alpina Hook. f. Dec.–Jan. Ruahine and Kaimanawa Mountains. Ascends to 5,000 ft. Waimarino (P. T.); volcanoes.

Dracophyllum recurvum Hook. f. Ruahine Mountains (Col.); volcanoes. Ascends to 5,000 ft. on Kaimanawa Mountains.
longifolium R. Br. Ascends to 4,500 ft.
Urvilleanum A. Rich. Volcanoes; Ruahine, Tararua, and Kaimanawa Mountains. 2,500–4,500 ft.
subulatum Hook. f. Nov.–Mar. Ruahine and Kaimanawa Mountains; Waimarino (P. T.). 350–3,500 ft.
uniflorum Hook. f. Dec.–Mar. Tararua Mountains. 2,000–4,500 ft.
rosmarinifolium R. Br. Dec.–Mar. Tararua Mountains (Buch.). 2,500–5,000 ft.

44. Primulaceae.

Samolus repens Pers. Nov.–Jan. Usually coastal.

45. Myrsinaceae.

Myrsine salicina Heward. Sept.–Dec. Ascends to 2,800 ft.
Urvillei A. D.C. Mar.–April. Ascends to 3,000 ft.
montana Hook. f. Ruahine Mountains (Col.); Taihape (Cock). Ascends to 3,000 ft.
divaricata A. Cunn. Aug.–Oct. Ascends to 4,000 ft.
nummularia Hook. f. Dec.–Jan. Ruapehu (Petrie); Ruahine Mountains (Col.); Tararua and Kaimanawa Mountains. 2,000–5,000 ft.

47. Oleaceae.

Olea Cunninghamii Hook. f. Oct.–Nov. Ascends to 2,500 ft.
lanceolata Hook. f. Nov.–Jan. Ascends to 2,000 ft.
montana Hook. f. Nov.–Jan. Ascends to 2,500 ft.

48. Apocynaceae.

Parsonsia heterophylla A. Cunn. Nov.–Mar. Fruit, April. Ascends to 2,500 ft.
capsularis R. Br. Nov.–Mar. Ascends to 2,000 ft.

49. Loganiaceae.

Logania depressa Hook. f. Locality possibly uncertain. Between Onetapu Desert, east of Ruapehu, and towards source of Moawhango River (Col.).
Geniostoma ligustrifolium A. Cunn. Oct.–Nov.

50. Gentianaceae.

Gentiana Grisebachii Hook. f. Dec.–Feb. Ruahine Mountains (Col.); Tongariro (Bidwill); Tararua Mountains; Kaimanawa Mountains. Ascends to 4,500 ft.
bellidifolia Hook. f. Jan.–Mar. Tararua and Kaimanawa Mountains; volcanoes. 1,500–5,800 ft.
patula Cheesem. Jan.–Mar. Tararua Mountains (Townson). 2,500–5,000 ft.
Liparophyllum Gunnii Hook. f. Dec.–Jan. Tararua and Kaimanawa Mountains; Mount Dennan; Quoin, 3,900 ft.; volcanoes (Cock., T. F. C.), 3,500–4,500 ft.

51. Boraginaceae.

Myosotis antarctica Hook. f. Nov.–Feb. Ascends to 4,500 ft.
Forsteri Lehm. Oct.–Feb. Ascends to 4,300 ft. on Kaimanawa Mountains.
petiolata Hook. f. Nov.–Jan. Ruahine Mountains (Hill). Ascends to 3,000 ft.
Astoni Cheesem. Dec.–Jan. Maungatiriri and Tauherenikau River valleys; Mount Holdsworth. 100–4,000 ft.

52. Convolvulaceae.

Calystegia sepium R. Br. Nov.–Mar.
turguriorum R. Br. Dec.–Feb.
Soldanella R. Br. Nov.–Mar. Coastal.
Convolvulus erubescens Sims. Dec.–Mar. Palliser Bay (Col., Buch.).
Dichondra repens Forst. Spring and early summer. Ascends to 2,500 ft.
brevifolia Buch. Nov.–Jan. Ascends to 3,000 ft.

53. Solanaceae.

Solanum nigrum Linn. Ascends to 2,000 ft.
aviculare Forst. Flowers most of the year.

54. Scrophularaceae.

Calceolaria Sinclairii Hook. Nov.–Feb. Ruahine Mountains. (Col., Petrie, &c.).
repens Hook. f. Dec.–Feb. Ruahine Mountains (Col.); Rimutaka Range (T. K.); Wainuiomata (Arnold); in creeks of Tararua Mountains; Makatote Gorge (T. F. C.). 250–2,000 ft.
Mazus pumilio R. Br. Nov.–Feb. Manawatu River (Col.); Otaki (Buch.); Pencarrow (T. K.); Levin Beach, Waikanae (Cah.).
radicans Cheesem. Wairarapa, Tararua Mountains (Col. and Buch.). 500–3,500 ft.
Mimulus repens R. Br. Nov.–Jan. Brackish swamps at Otaki (E. H Atkinson).
Gratiola peruviana Linn. Nov.–Feb. Ascends to 1,500 ft.
Glossostigma elatinioides Benth. Nov.–Feb. Ascends to 2,500 ft.
Limosella tenuifolia Nutt. Nov.–Feb. Ascends to 3,000 ft.
Veronica speciosa R. Cunn. Nov.–Mar. Port Nicholson (Lyall).
macroura Hook. f. Cook Strait (Cock.). Identification doubtful (T. F. C.).
salicifolia Forst. Dec.–Mar. Ascends to 3,500 ft.
rotundata T. K. July–Sept. Vicinity of Wellington (T. K.).
angustifolia A. Rich. Dec.–Feb. River-beds of Wangaehu and Turakina (A. Allison).
parviflora Vahl. Dec.–Feb. Wellington.
venustula Col. East side Ruahine Mountains (Col.).
Colensoi Hook. f. Rangitikei (D. P.); Ruahine Mountains (Col.); Kaimanawa Mountains. Ascends to 3,000 ft.
laevis Benth. Dec.–Feb. Ruahine Mountains (Col.); volcanoes; Tararua and Kaimanawa Mountains. 2,500–5,000 ft.
elliptica Forst. Dec.–Feb. Titahi Bay. Coastal.

Veronica buxifolia Benth. Dec.–Mar. Tararua and Kaimanawa Mountains; volcanoes (Cheesem.). 2,000–5,000 ft.

tetragona Hook. Jan.–Feb. Volcanoes; Kaimanawa Mountains. 2,000–5,000 ft.

Astoni Petrie. Tararua Mountains. 4,000–5,000 ft.

catarractae Forst. Nov.–Jan. Ascends to 4,000 ft.

catarractae var. *diffusa* Hook. f. Tararua Mountains, 5,000 ft.; Tauherenikau Valley, 1,000 ft.; volcanoes (T. F. C.).

Lyallii Hook. Nov.–Mar. Ruahine and Tararua Mountains (Cheesem.); Wanganui (Buch.). Ascends to 4,500 ft.

Hookeriana Walp. Volcanoes (Cheesem., Cock., Turner). 3,000–6,000 ft.

Olseni Col. Dec.–Mar. Ruahine Mountains (Col. and Petrie). 2,000–4,000 ft.

spatulata Benth. Volcanoes; Ruahine Mountains (Hill), 3,000–7,000 ft.; on Ruapehu (Cock.).

Ourisia macrophylla Hook. Nov.–Jan. Wainuiomata (Buch.); Kaimanawa Mountains. Ascends to 4,500 ft.

Colensoi Hook. f. Nov.–Jan. Tararua and Ruahine Mountains and volcanoes, 1,500–3,500 ft. Ascends to 5,000 ft. on Kaimanawas.

caespitosa Hook. f. Dec.–Feb. Ruahine, Kaimanawa, and Tararua Mountains, and volcanoes. 3,000–6,500 ft.

Euphrasia cuneata Forst. Dec.–Mar. Ascends to 5,000 ft. on Kaimanawas.

revoluta Hook. f. Dec.–Mar. Ruahine (Col.) and Tararua and Kaimanawa Mountains. 2,500–5,500 ft.

zealandica Wetts. Dec.–Mar. Ruahine and Tararua Mountains. 2,000–6,000 ft. Northern limit, Pukeonake, west of Tongariro (T. F. C.).

55. Lentibulariaceae.

Utricularia novae-zealandiae Hook. f. Nov.–Jan. Palliser Bay (Col.).

monanthos Hook. f. Dec.–Mar. Rangipo Plain (Petrie); volcanoes (T. F. C.); Kaimanawa Mountains. Ascends to 4,500 ft.

56. Gesneraceae.

Rhabdothamnus Solandri A. Cunn. Flowers most of the year. Upper Wairarapa (Buch.); Wellington (T. F. C.); Waimarino (Turner); Wanganui (E. H. Atkinson). Ascends to 2,000 ft.

57. Myoporaceae.

Myoporum laetum Forst. Oct.–Jan. Usually coastal.

58. Verbenaceae.

Teucridium parviflorum Hook. f. Oct.–Jan. Rare. Ascends to 800 ft. at Kakahi (Turner).

59. Labiatae.

Mentha Cunninghamii Benth. Ascends to 4,500 ft.

60. Plantaginaceae.

Plantago Raoulii Decne. Upper Rangitikei (Buch.). Ascends to 3,500 ft.

spatulata Hook. f. Between Castle Point and Cape Palliser.

Brownii Rapin. Tararua Mountains (Buch.); Ruahine Mountains (Col.). Ascends to 5,500 ft.

uniflora Hook. f. Ruahine Mountains (Col.); Tararua Mountains. 4,000–5,000 ft.

62. Illecebraceae.

Scleranthus biflorus Hook. f. Ascends to 4,000 ft.

64. Chenopodiaceae.

Rhagodia nutans R. Br. Coastal.
Chenopodium triandrum Forst. Nov.–Mar. Mostly coastal.
glaucum Linn. Nov.–Mar. Mostly coastal.
carinatum R. Br. Dec.–Mar. (Buch.).
Atriplex cinerea Poir. Palliser Bay (Col.).
patula (Linn.).
Buchananii T. K. Dec.–Mar. Wellington (Buch. and Kirk).
Salicornia australis Sol. Summer and autumn. Coastal.
Suaeda maritima Dum. Dec.–Mar. Coastal.
Salsola Kali Linn. Dec.–Mar.

65. Polygonaceae.

Polygonum aviculare Linn. Nov.–Mar. Ascends to 2,500 ft.
serrulatum Lag. Nov.–Mar. Wellington (Buch.).
Rumex flexuosus Sol. Dec.–Mar. Ascends to 4,000 ft.
neglectus T. K. Nov.–Mar. Beaches near Wellington.
Muehlenbeckia australis Meissn. Nov.–April. Ascends to 2,000 ft.
complexa Meissn. Nov.–April. Ascends to 3,500 ft. on Kaimanawa Mountains.
axillaris Walp. Dec.–Mar. Ascends to 4,500 ft.
Astoni Petrie. Wainuiomata mouth; Orongorongo.
ephedrioides Hook. f. Dec.–Mar. Upper Rangitikei (Williams, Petrie) Ascends to 3,000 ft.

66. Piperaceae.

Piper excelsum Forst. Flowers most of the year.
Peperomia Endlicheri Miq. Titahi and Evans Bays.

67. Chloranthaceae.

Ascarina lucida Hook. f. Sept.–Nov. Wairarapa Valley (Col.).

68. Monimiaceae.

Hedycarya arborea Forst. Oct.–Nov. Ascends to 2,500 ft.
Laurelia novae-zealandiae A. Cunn. Oct.–Nov. Ascends to 2,000 ft.

69. Lauraceae.

Beilschmiedia tawa Benth & Hook. f. Nov.–Dec. Fruit, January. Ascends to 2,500 ft.

70. Proteaceae.

Knightia excelsa R. Br. Nov.–Dec. Ascends to 2,800 ft.

71. Thymelaeaceae.

Pimelia longifolia Banks & Sol. Oct.–Dec. Tararua Mountains. Ascends to 3,000 ft.
Gnidia Willd. Dec.–Jan. Ruahine Mountains (Col.); Tararua Mountains. Ascends to 4,000 ft.

Pimelia buxifolia Hook. f. Jan.–Mar. Ruahine Mountains (Petrie); Kaimanawa Mountains; volcanoes (T. F. C.). 1,500–5,500 ft.
virgata Vahl. Sept.–Dec. Wellington. Uncommon. Ascends to 2,000 ft.
arenaria A. Cunn. Nov.–Mar. Coastal.
laevigata Gaertn. Oct.–Mar. Ascends to 5,000 ft. on Kaimanawa Mountains.
Lyallii Hook. f. Dec.–Mar. Ruahine Mountains (Col., Tryon, Hamilton). 2,000–4,500 ft.
Drapetes Dieffenbachii Hook. Dec.–Mar. 2,000–4,500 ft.

72. Loranthaceae.

Loranthus micranthus Hook. f. Oct.–Nov. Ascends to 2,000 ft.
tetrapetalus Forst. Nov.–Jan. Quoin, 2,900 ft.; volcanoes. Ascends to 4,000 ft. on Kaimanawas.
Colensoi Hook. f. Dec.–Jan. Ascends to 2,000 ft.
Fieldii Buch. Base of Ruapehu (H. C. Field).
flavidus Hook. f. Dec.–Feb. Ruahine Mountains (T. F. C.). Ascends to 3,500 ft. on Kaimanawas.
Tupeia antarctica Cham. & Schl. Oct.–Dec. Ascends to 3,000 ft.
Viscum Lindsayi Oliver. Oct.–Feb. Lake Wairarapa Road.
salicornioides A. Cunn. Ascends to 1,500 ft.

73. Santalaceae.

Fusanus Cunninghamii Benth. & Hook. f. Sept.–Oct. Fruit, March. Waikanae.

74. Balanophoraceae.

Dactylanthus Taylori Hook. f. Feb.-Mar. Waitotara, Upper Rangitikei, Upper Wanganui (T. F. C.); Kaitoke (Phillips); near Pipiriki (E. P. Turner).

75. Euphorbiaceae.

Euphorbia glauca Forst. Oct.–Feb. Coastal.

76. Urticaceae.

Paratrophis heterophylla Bl. Oct.–Feb. Sparsely distributed throughout. Ascending to 1,000 ft. at Waimarino (Turner).
Banksii Cheesem. Nov.–Feb. Cook Strait; Wainuiomata Valley.
Urtica ferox Forst. Aug.-Dec. Ascends to 1,000 ft.
incisa Poir. Flowers spring and summer. Ascends to 4,000 ft.
incisa var. *linearifolia* Hook. f. Near Levin, Lake Papaitonga, at edges of creeks.
Elatostemma rugosum A. Cunn. Middle Wellington Province (Cheesem.); Otaki (Buch.); Ohau River; Levin.
Parietaria debilis Forst. Flowers spring and summer. Ascends to 2,500 ft.
Australina pusilla Gaud. Ascends to 1,000 ft.

77. Fagaceae.

Fagus Menziesii Hook. f. Nov.–Jan. Ascends to 4,000 ft.
fusca Hook. f. Oct.–Dec. Ascends to 3,500 ft.
apiculata Col. Nov.–Dec. River-flats on Maungatiriri River, and Kaitoke; Day's Bay (E. H. A.).

Fagus Blairii T. K. Forest near source of Wanganui River (T. K.). 1,000–2,500 ft.
Solandri Hook. f. Nov.–Dec. Ascends to 2,500 ft.
cliffortioides Hook. f. Dec.–Jan. Waimarino (Turner); volcanoes (Cock.), Kaimanawa Mountains. 2,000–4,000 ft.

78. Taxaceae.

Libocedrus Bidwillii Hook. f. 800–4,000 ft.
Podocarpus totara Don. Ascends to 2,000 ft.
Hallii T. K. Ascends to 4,000 ft. on Kaimanawa Mountains.
nivalis Hook. Waimarino (Turner); Kaimanawa Mountains; Tararua Mountains (Buch.). 2,000–5,500 ft.
ferrugineus Don. Ascends to 3,000 ft.
spicatus R. Br. Ascends to 2,000 ft.
dacrydioides A. Rich. Ascends to 2,000 ft.
Dacrydium biforme Pilger. Waimarino (Turner); Ruahine Mountains (T. F. C.). 2,000–4,500 ft.
Bidwillii Hook. f. Ruahine Mountains (Col.); volcanoes; Kaimanawas. 2,000–4,500 ft.
cupressinum Sol. Ascends to 2,500 ft.
intermedium T. K. Ruahine Mountains (Col.); Tararua Mountains. Ascends to 4,000 ft.
Colensoi Hook. f. Waimarino Forest (T. K., Turner): volcanoes (Cock.). Ascends to 3,000 ft.
laxifolium Hook. f. Ruahine Mountains (Col.); volcanoes, 2,500–4,000 ft.; Kaimanawa Mountains, to 5,000 ft.
Phyllocladus trichomanoides Don. Tararua Mountains (Buch.). Ascends to 2,500 ft.
alpinus Hook. f. Waimarino district (Turner); volcanoes (Cock.); Kaimanawa Mountains.

79. Orchidaceae.

Dendrobium Cunninghamii Lindl. Dec.–Feb. Ascends from sea-shore to 2,000 ft.
Bulbophyllum tuberculatum Col. April–May. Palmerston North (Hamilton).
pygmaeum Lindl. Nov.–Feb. Happy Valley Bay. Ascends to 1,500 ft.
Earina mucronata Lindl. Oct.–Dec. Ascends to 2,000 ft.
suaveolens Lindl. Mar.–June. Ascends to 2,000 ft.
Sarcochilus adversus Hook. f. Oct.–Nov.
Spiranthes australis Lindl. Jan.–Feb. Bog near Erua, 2,600 ft. (P. Turner).
Thelymitra longifolia Forst. Nov.–Dec. Ascends to 4,000 ft.
decora Cheesem. Jan. Volcanoes; Taumarunui (T. F. C.); Kaimanawas. 2,500–3,700 ft.
venosa R. Br. Mungaroa Swamp (T. K., Petrie).
uniflora Hook. f. Dec.–Jan. Volcanoes (T. F. C.). Ascends to 3,500 ft.
Orthoceras strictum R. Br. Dec.–Feb. Ascends to 2,500 ft.
Microtis porrifolia R. Br. Oct.–Dec. Ascends to 2,500 ft.
Prasophyllum Colensoi Hook. f. Nov.–Jan. Ascends to 5,000 ft. on Kaimanawas.
rufum R. Br. Feb. Day's Bay; Kaitoke; Waimarino, at 2,900 ft. (Turner).

Pterostylis Banksii R. Br. Oct.–Nov. Ascends to 3,500 ft.
graminea Hook. f. Sept.–Nov.
micromega Hook. f. Dec.–Jan. Murimotu (Petrie); Wairarapa (Col.).
foliata Hook. f. Dec.–Jan. Ruahine Mountains and Cape Palliser (Col.); Kaitoke. Ascends to 2,500 ft.
venosa Col. Ruahine Mountains (Olsen). 2,000–3,500 ft.
trullifolia Hook. f. Kaitoke (V. Phillips, B. C. A.).
barbata Lindl. Oct.–Nov. Kaitoke (V. Phillips, B. C. A.); Day's Bay (Atkinson, Morrison).
Acianthus Sinclairii Hook. f. May–Aug. Kapiti Island (Cock.). Ascends to 2,500 ft.
Cyrtostylis oblonga Hook. f. Aug.–Oct. Kaitoke (V. Phillips). Ascends to 2,500 ft.
Calochilus paludosus R. Br. Upper Hutt (E. H. Atkinson).
Lyperanthus antarcticus Hook. f. Dec.–Feb. Tararua Mountains. 3,000–4,000 ft.
Caladenia minor Hook. f. Sept.–Dec. Kaitoke. Ascends to 2,000 ft.
bifolia Hook. f. Dec.–Jan. Tararua Mountains; volcanoes (T. F. C.). Ascends to 4,500 ft.
Chiloglottis cornuta Hook. f. Oct.–Dec. Kaitoke; Kaimanawa Mountains. Ascends to 3,000 ft.
Adenochilus gracilis Hook. f. Nov.–Jan. Between Ohakune and Ruapehu (Turner). 500–2,500 ft.
Corysanthes rotundifolia Hook. f. Sept.–Dec. Ascends to 2,500 ft.
triloba Hook. f. July–Sept. Ascends to 4,000 ft. on Kaimanawa Mountains.
macrantha Hook. f. Oct.–Dec. Ascends to 3,500 ft. on Kaimanawa Mountains.
Gastrodia sesamoides R. Br. Dec.–Jan. Tauherenikau Valley. Ascends to 1,500 ft.
Cunninghamii Hook. f. Nov.–Jan. Ascends to 2,000 ft.

80. Iridaceae.

Libertia ixioides Spreng. Oct.–Dec. Ascends to 3,500 ft. on Kaimanawa Mountains.
ixioides var. *b*. Levin Beach. Coastal.
grandiflora Sweet. Oct.–Nov.
pulchella Spreng. Nov.–Jan. Ascends to 4,000 ft.

82. Liliaceae.

Rhipogonum scandens Forst. Nov.–Dec. Fruit, January. Ascends to 2,000 ft.
Enargia marginata Banks & Sol. Nov.–Feb. Ascends to 3,500 ft.
Cordyline Banksii Hook. f. Nov.–Dec. Ascends to 3,500 ft.
australis Hook. f. Nov.–Jan. Ascends to 2,500 ft.
indivisa Steud. Dec.–Jan. 1,500–4,000 ft.
pumilio Hook. f. Nov.–Dec. Ascends to 1,500 ft. (Buch., T. F. C.).
Astelia linearis Hook. f. Nov.–Jan. 3,000–5,000 ft.
Cunninghamii Hook. f. Dec.–Jan. Fruit, Nov.–Dec. Ascends to 2,500 ft.
trinervia T. K. Mar.–May. Fruit, Feb.–Mar. Ascends to 3,000 ft.
Solandri A. Cunn. Jan.–Feb. Ascends to 2,700 ft.
nervosa Banks & Sol. Oct.–Jan. Ascends to 4,500 ft.
Dianella intermedia Endl. Nov.–Dec. Ascends to 2,500 ft.

Phormium tenax Forst. Nov.–Jan. Ascends to 4,000 ft.
Cookianum Le Jolis. Nov.–Jan. Ascends to 4,000 ft.
Bulbinella Hookeri Benth. & Hook. f. Oct.–Jan. Ascends to 4,500 ft.
Arthropodium cirrhatum R. Br. Nov.–Dec.
candidum Raoul. Nov.–Jan. Ascends to 3,500 ft.
Herpolirion novae-zealandiae Hook. f. Dec.–Jan. Tararua and Kaimanawa Mountains; volcanoes.

83. Juncaceae.*

Juncus pauciflorus R. Br. Dec.–Feb. Ascends to 2,500 ft.
vaginatus R. Br. Dec.–Feb.
effusus Linn. Nov.–Feb. Ascends to 3,000 ft.
maritimus Lam. var. *australiensis*. Dec.–Jan.
bufonius Linn. Nov.–Jan. Ascends to 4,000 ft.
planifolius R. Br. Nov.–Jan. Ascends to 3,000 ft.
antarcticus Hook. f. Dec.–Feb. Tararua Mountains; Rangipo Plain (Petrie). 1,500–4,000 ft.
prismatocarpus R. Br. Nov.–Jan.
holoschoenus R. Br. Nov.–Feb. Ascends to 2,500 ft.
lampocarpus Ehr. Nov.–Feb. Ascends to 3,500 ft.
novae-zealandiae Hook. f. Dec.–Mar. Tararua and Kaimanawa Mountains. Ascends to 4,500 ft.
Luzula Colensoi Hook. f. Jan.–Feb. Mount Holdsworth (Townson); Ruahine Mountains (Col.); Ngauruhoe. 4,000–6,500 ft.
campestris D. C. Ascends to 5,000 ft. on Kaimanawa Mountains.

84. Palmeae.

Rhopalostylis sapida Wendl. & Drude. Jan.-April. Ascends to 2,000 ft.

85. Pandanaceae.

Freycinetia Banksii A. Cunn. Sept.–Nov. Fruit, May. Ascends to 2,500 ft.

86. Typhaceae.

Typha angustifolia Linn. Dec.–Mar. Ascends to 2,000 ft.
Sparganium antipodum Graeb. Dec.-Mar.

87. Lemnaceae.

Lemna minor Linn. Ascends to 2,000 ft.

88. Naiadaceae.

Triglochin striatum Ruiz & Pav. Oct.–Jan.
Potamogeton Cheesemanii A. Bennett. Nov.–Mar. Volcanoes, 4,250 ft. (T. F. C.).
natans Linn.
polygonifolius Pourr. Dec.–April. Ascends to 4,700 ft. on Kaimanawa Mountains.
ochreatus Raoul. Nov.–Mar. Turakina River mouth (Cock.).
pectinatus L. Dec.–Mar. Turakina River mouth (Cock.).
Ruppia maritima Linn. Dec.–April.
Zostera nana Roth.

* *J. scheuchzerioides* was included in my list of Tararua plants (Trans. N.Z. Inst., vol. 42, p. 13) through a clerical error.

89. Centrolepidaceae.

Centrolepis pallida Cheesem. Dec.–Mar. Ruahine Mountains (Col.).
viridis T. K. Dec.–Mar. Base of Ruapehu (Petrie); Kaimanawa Mountains. 2,000–5,000 ft.

90. Restiaceae.

Leptocarpus simplex A. Rich. Sept.–Dec.
Hypolaena laterifolia Benth. Nov.–Mar. Ascends to 4,500 ft.

91. Cyperaceae.

Cyperus vegetus Willd. Nov.–Jan.
Mariscus ustulatus Clarke. Nov.–Jan. Ascends to 1,500 ft.
Eleocharis acuta R. Br. Nov.–Mar. Ascends to 3,500 ft. on Kaimanawas.
Cunninghamii Boeck. Nov.–Mar. Ascends to 4,500 ft. on volcanoes (T. F. C.).
Scirpus lenticularis Poir. Dec.–Mar. Base of Ruapehu (D. P., Hamilton). Ascends to 2,500 ft.
aucklandicus Boeck. Dec.–Mar. Ruahine (Col.). Ascends to 5,000 ft.
cernuus Vahl. Nov.–Feb. Ascends to 2,000 ft.
antarcticus Linn. Nov.–Mar. Ascends to 2,000 ft.
inundatus Poir. Nov.–Mar. Ascends to 3,000 ft.
sulcatus Thouars. Nov.–Mar. Ascends to 2,000 ft.
prolifer Rottb. Nov.–Mar.
frondosus Banks & Sol. Nov.–Feb. Coastal.
americanus Pers. Nov.–Feb. Palliser Bay; Marton (Townson).
lacustris Linn. Nov.–Feb. Ascends to 1,500 ft.
maritimus Linn. Nov.–Feb.
Carpha alpina R. Br. Dec.–Feb. 2,500–5,000 ft.
Schoenus brevifolius R. Br. Dec.–Jan. Ascends to 1,500 ft.
Tendo Banks & Sol. Oct.–Jan. Ascends to 2,000 ft.
pauciflorus Hook. f. Dec.–Mar. 1,500–5,000 ft.
axillaris Poir. Nov.–Mar. Ascends to 2,500 ft.
nitens Poir. Dec.–Mar. Ascends to 2,500 ft.
nitens var. *concinnus*. Ascends to 4,500 ft. on volcanoes (T. F. C.).
Cladium Sinclairii Hook. f. Oct.–Jan. Patea (Cock.); Taihape. Ascends to 2,000 ft.
glomeratum R. Br. Nov.–Jan. Ascends to 2,000 ft.
Gunnii Hook. f. Dec.–Jan. Ascends to 2,500 ft.
junceum R. Br. Nov.–Jan. Ascends to 2,000 ft.
Vauthiera Clarke. Nov.–Jan. Ascends to 2,000 ft.
Gahnia setifolia Hook. f. Dec.–Feb. Ascends to 2,000 ft.
pauciflora T. K. Oct.–Dec. Ascends to 3,000 ft.
xanthocarpa Hook. f. Feb.–Mar. Ascends to 2,500 ft.
lacera Steud. July–Aug. Ascends to 2,000 ft.
Gaudichaudii Steud. Ascends to 2,000 ft.
Oreobolus strictus Bergg. Tararua and Kaimanawa Mountains, 3,500–5,000 ft.; Rangipo Plain (Hill).
Uncinia purpurata Petrie. Dec.–Jan. Tararua Mountains (D. P.). 1,000–4,000 ft.
compacta R. Br. Dec.–Feb. Ruahine Mountains (Cock.); Tararua Mountains (Buch.). 1,000–5,500 ft.
caespitosa Boott. Nov.–Jan. Ascends to 4,000 ft.

Uncinia uncinata Linn. f. Nov.–Feb. Ascends to 3,000 ft.
leptostachya Raoul. Nov.–Jan. Ascends to 3,000 ft.
riparia R. Br. Nov.–Jan. Ascends to 3,000 ft.
rubra Boott. Dec.–Feb. Waimarino (T. F. C.).
rupestris Raoul. Tararua Mountains (H. H. T.); Ruahine Mountains (Col.).
filiformis Boott. Dec.–Jan. Ruahine Mountains (Col.); Tararua Mountains. 1,000–4,500 ft.
Carex pyrenaica Whal. Dec.–Mar. Ruahine Mountains (Col.). 3,500–6,500 ft.
acicularis Boott. Dec.–Mar. Ruahine Mountains (Col.); Tararua Mountains; Tongariro (Col.). 2,500–5,000 ft.
diandra Schrank. Dec.–Mar. Ascends to 3,000 ft.
virgata Soland. Nov.–Jan. Ascends to 3,000 ft.
secta Boott. Nov.–Jan. Ascends to 2,500 ft.
inversa R. Br. Nov.–May. Ascends to 3,000 ft.
Colensoi Boott. Nov.–Mar. Ascends to 4,000 ft.
echinata Murr. Nov.–Mar. Ascends to 4,000 ft.
leporina Linn. Nov.–Jan. Ohariu Valley (T. K.). Ascends to 4,000 ft.
Gaudichaudiana Kunth. Nov.–Feb. Ascends to 4,500 ft.
subdola Boott. Nov.–Jan. Ascends to 1,500 ft.
ternaria Forst. Nov.–Feb. Ascends to 4,000 ft.
dipsacea Bergg. Nov.–Jan. Ascends to 3,000 ft.
testacea Sol. Oct.–Jan. Ascends to 3,500 ft.
lucida Boott. Oct.–Jan. Ascends to 3,000 ft.
Petriei Cheesem. Dec.–Feb. Ascends to 3,500 ft. on Kaimanawas.
dissita Sol. Oct.–Jan. Ascends to 3,500 ft.
breviculmus R. Br. Oct.–Mar. Ascends to 3,000 ft.
pumila Thunb. Oct.–Jan.
Forsteri Wahl. Nov.–Jan. Ascends to 2,000 ft.
pseudocyperus Linn. Nov.–Feb. Ascends to 3,000 ft.

92. Gramineae.

Zoysia pungens Willd. Ascends to 2,000 ft.
Paspalum Digitaria Poir. Sydney Street, Wellington.
Oplismenus undulatifolius Beauv.
Spinifex hirsutus Labil. Coastal.
Ehrharta Colensoi Hook. f. Ruahine and Tararua Mountains. 3,000–5,500 ft.
Microlaena stipoides R. Br. Ascends to 2,000 ft.
avenacea Hook. f. Dec.–Jan. Ascends to 3,500 ft. on Kaimanawa Mountains.
polynoda Hook. f. Dec.–Jan. Base of Ruahine Mountains (Col.). Ascends to 1,500 ft.
Hierochloe redolens R. Br. Ascends to 3,000 ft.
Fraseri Hook. f. Ascends to 5,000 ft. on volcanoes (T. F. C.).
Stipa arundinacea Benth. Wairarapa (Buch.); South Karori (Kirk). Ascends to 1,500 ft.
Echinopogon ovatus Beauv. Ascends to 2,500 ft.
Alopecurus geniculatus Linn. Wairarapa (Buch.); near Wellington (T. K.). Ascends to 3,500 ft.
Sporobolus indicus R. Br.
Simplicia laxa T. K. Lower Wairarapa (T. K.).

Agrostis muscosa T. K. Tararua and Kaimanawa Mountains; volcanoes. 1,500–4,500 ft.
Muelleri Benth. Ruahine Mountains (Col.). 2,500–5,500 ft.
Dyeri Petrie. Volcanoes (T. F. C.); Tararua and Kaimanawa Mountains. 1,000–5,500 ft.
Deyeuxia Forsteri Kunth.* Ascends to 3,000 ft.
Billardieri Kunth. Coastal.
setifolia Hook. f. 3,000–5,000 ft.
quadriseta Benth. Ascends to 2,500 ft.
Dichelachne crinita Hook. f. Ascends to 3,000 ft.
sciurea Hook. f.
Deschampsia caespitosa Beauv. Palliser Bay. Ascends to 3,500 ft.
tenella Petrie. Ruahine Mountains (Col.); Tararua Mountains (Travers). Ascends to 4,500 ft.
Trisetum antarcticum Trin. Ascends to 4,500 ft.
Youngii Hook. f. Tararua Mountains; volcanoes (T. F. C.). 3,000–5,000 ft.
subspicatum Beauv. Ascends to 5,000 ft.
Amphibromus fluitans T. K. Marton (Townson).
Danthonia Cunninghamii Hook. f. Ascends to 3,500 ft.
bromoides Hook. f. Near Cape Palliser (Buch.); near Wellington (Stephenson).
Raoulii Steud. Ascends to 5,000 ft.
pilosa R. Br. Ascends to 4,500 ft.
semiannularis R. Br. Ascends to 7,000 ft. on Ruapehu (Cock.).
Arundo conspicua Forst. Ascends to 3,500 ft. on Kaimanawa Mountains.
fulvida Buch.
Triodia australis Petrie. Mount Hector. 3,000–5,000 ft.
Poa novae-zealandiae Hack. Tararua Mountains.
anceps Forst. Ascends to 3,500 ft.
seticulmis Petrie. Tauherenikau Valley. Ascends to 2,500 ft.
caespitosa Forst. Ascends to 4,000 ft.
Colensoi Hook. f. 1,000–5,000 ft.
Kirkii Buch. Tararua Mountains.
imbecilla Forst. Tararua Mountains. Ascends to 4,000 ft.
Atropis stricta Hack. Coastal.
Festuca littoralis Labill. Coastal.
ovina Linn. Ascends to 4,500 ft.
rubra Linn. Ascends to 4,500 ft.
Agropyrum multiflorum T. K. Day's Bay.
scabrum Beauv. Ascends to 4,500 ft.
Asperella gracilis T. K. Dannevirke (Col.); Turangaarere (Petrie). Ascends to 3,000 ft.

* By a clerical error *D. Petriei* was included in my list of Tararua plants (Trans. N.Z. Inst., vol. 42, p. 13).

Art. XXIX.—*Notes on the Botany of Lake Hauroko District.*

By J. Crosby Smith, F.L.S.

[*Read before the Otago Institute, 2nd August, 1910.*]

Having long had the desire to make a botanical excursion to the mountains lying to the west of the great Waiau River, in the south-west of the fiord country, and especially to those parts surrounding Lake Hauroko, and known as the Princess Mountains, I welcomed the opportunity of doing this that presented itself in February of this year (1910). Our party consisted of Mr. Robert Gibb, Mr. Vernon C. Smith, and myself.

Having crossed the Waiau, our route to the lake lay by the main road through the bush, past Clifden, and on past the Lillburn, to what is known as Gardner's, or the "end of the track." Two miles from Gardner's the track leads on to low peaty land extending for a mile, which has until recently been covered by a young forest of bog-pine (*Dacrydium Bidwillii*). We were informed by Mr. Gardner that this bog-pine had been burnt out during the previous dry summer. Gradually the "birch" forest (*Fagus Solandri* and *F. Menziesii*) is reached, and continues more or less for the rest of the distance to the lake. Here and there in the gullies, which are very numerous, will be found *Coprosma foetidissima*, *C. rotundifolia*, *Metrosideros lucida*, *Panax Colensoi*, *Senecio elaeagnifolius*, *Drimys colorata*, *Leptospermum scoparium*, and others; also *Dicksonia squarrosa*, *Hemitelia Smithii*, *Aspidium flavidum*, *Lomaria fluviatilis*, *L. discolor*, *Gleichenia Cunninghamii*, *Pteris aquilina*, *P. incisa*, *Asplenium bulbiferum*, *Todea superba*, and *Hymenophyllum* spp.

As the lake was neared the vegetation became thicker and the ferns more numerous and taller. The first glimpse of the lake, as its waters glimmer and shimmer through the trees in the bush, is beautiful The track comes out on a long arm of the lake facing Mary Island, a distance of five or six miles from the lower end of the lake. Across the lake the high mountains of the Princess Range, with their towering peaks of Albert Edward and Alexandra, form a majestic background. These mountains appear almost precipitous, being bush-clad up to 3,000 ft. or more, the bare tops being covered with the usual alpine flora.

As there is no record of a botanist having visited the lake previously (except perhaps Mr. G. M. Thomson, in the early "eighties," but who on account of bad weather did no collecting), we had decided to examine both sides of the lake for plants and birds, and for this purpose we hired a boat. As we opened up the lake we found the shores to consist entirely of precipitous wooded hills, nowhere less than 3,000 ft., and rising to 5,000 ft., with sharp and rugged peaks, and with more than a score of waterfalls shooting on both sides. With the exception of a couple of beaches from one to two acres in extent, there is no flat land. The only other possible landing-places are where the many steep creeks or waterfalls have filled up the edge of the lake with boulders · consequently, until we reached the head of the lake, it was only on these small patches we could land to make investigations.

Lake Hauroko is about twenty-five miles long by one mile wide, and, being formed at the bottom of a deep gully, becomes most treacherous to a rowing-boat, the wind sweeping down it as down a funnel. On account of

this it took us three days to reach the head of the lake, during which time we had been consuming the provisions we had intended for an extended land journey.

At the head of the lake we pitched camp, and made excursions some distance up the Hauroko River, and also up Hay River. On the flat at the junction of the Hauroko River with the lake there is a piece of country that might well be the habitat of such a bird as the takahe, but after a careful search we found no traces of such a bird.

On the western side, at the head of the lake, the vegetation in the bush is most luxuriant; especially is this the case with ferns and mosses. Our object was to climb End Peak, a name which was given to the last, or end, peak of the Princess Range. It lies near the head of Hay River, on the western side, and is about 4,500 ft. high. Making an early start, we struck into the bush half a mile below Hay River. We had to make our own track through 3,000 ft. of dense bush, blazing it as we went along. Now and again we struck Mr. Hay's blazed trees of thirty years ago, and it was this that led us on to a very serviceable razorback ridge, and for some time kept us clear of deep gullies.

After a five hours' climb we reached the clearing, at an elevation of 3,500 ft. Another hour sufficed to find us on the highest point of the peak.

For a height of nearly 2,500 ft. there is little variation in the character of the vegetation, which differs very little indeed from that of the lower elevations on the eastern side. The trees and shrubs were much the same, with the addition perhaps of *Panax lineare, Pittosporum Colensoi*, a couple of species of *Coprosma*, and one or two others. Up to this point very little of the usual thinning-out of the bush on account of elevation could be detected; the trees were as thick and as tall and straight as lower down. After this height the stunting gradually began; the trees became scarcer, and *Coprosmas* became more plentiful, and gradually the mountain-flora began to make its appearance.

Although it was nearly the end of February, we were rewarded with a very large number of plants in flower, especially of *Celmisia*, and very fortunately so with a new species of *Olearia* and of *Aciphylla*.

Next day, as our provisions were getting low, we decided to pull ourselves to the foot of the lake, some twenty-five miles, which was done in nine hours, with only one stoppage of an hour for rest and lunch. At the foot of the lake, on the eastern side, there is a mountain known as the Hump, 3,500 ft. high, over which an old sheep-track passes, leading down to the coast some sixteen miles below the Waiau mouth. As I was desirous of comparing the vegetation of the Hump with that on End Peak, we decided to find this track, and make for home by that route. For a distance of half a mile this track is now completely overgrown and difficult to find; but once the ascent of the hill commences it is well defined, but becomes very steep, especially for the last 1,500 ft. This ascent occupied us nearly the whole day, and, a fog coming over as we reached the top, we pitched the tent and turned in for the night. Next morning, being clear on the top, gave us an opportunity to examine the vegetation and collect. I was not very greatly surprised to find the plants on the Hump almost identically the same as those on End Peak, as the elevation and bird-life were much the same. As far as I could observe, there were only about half a dozen plants different—that is, all the plants found on the Hump were also found on End Peak. The geological structure was much the same, the soil being peaty, and the rock mica-schist and gneiss (white granite).

Botanically the trip may be considered very satisfactory, as the plants noted cover 225 species and forty-five orders. Mr. D. Petrie has kindly looked through my material, from which, in another place, he is describing no less than five new species, named as follows: *Euphrasia australis* (Petrie), *Aciphylla pinnatifida* (Petrie), *Gentiana flaccida* (Petrie), *Olearia Crosby-Smithiana* (Petrie), *Danthonia* (?) *barbata* (Petrie). These are all very distinct. *Euphrasia australis* has creamy-yellow flowers. *Aciphylla pinnatifida* is far removed from any other New Zealand species, and would appear to be almost unique. *Olearia Crosby-Smithiana* Mr. Petrie considers "one of the most distinct species of the genus," nearest perhaps to *O. lacunosa*, having very narrow linear leaves with a besom-like habit of growth, 6–15 in. high. The *Danthonia* (?) cannot be described till flowers are procured; but its strong characteristic is that all the leaves are densely ciliate, giving the appearance of being barbed. Of other plants, some are very rare, as, for instance, *Celmisia Traversii*, the most beautiful of all the *Celmisias*, which is the first discovery of this plant to the south of Lake Tennyson.

Until flowering specimens are obtained, the species of several other plants will have to be left in abeyance, as, for instance, the plant put down temporarily as *Aristotelia* (?) *fruticosa* probably does not belong to this genus at all.

There yet remains much work to be done in the Hauroko district, or the country between Lake Monowai and Long Sound, and the botanist who undertakes it will, I am sure, meet with a rich reward.

List of Plants collected.

Ranunculaceae.

Ranunculus Lyallii. End Peak and Hump.
sp. End Peak.
Buchanani. Hump.
ternatifolius. End Peak.
Clematis indivisa. Common.

Magnoliaceae.

Drimys colorata. Common.

Cruciferae

Cardamine hirsuta var. *debilis.* Common.
depressa. Lake flat.

Violaceae.

Viola Cunninghamii. End Peak.
Lyallii. Hump.

Pittosporaceae.

Pittosporum Colensoi. Common.
tenuifolium. Common.
eugenioides. Common.

Tiliaceae.

Aristotelia (?) *fruticosa* End Peak; rare; 2,500 ft.
racemosa. Common.

Geraniaceae.

Geranium microphyllum. Lake flat.

Coriariaceae.

Coriaria thymilifolia. End Peak and Hump.
angustissima. End Peak and Hump.
ruscifolia. Common.

Leguminosae.

Carmichaelia sp. End Peak.
Sophora tetraptera. Common.

Rosaceae.

Geum parviflorum. End Peak and Hump.
Acaena Sanguisorbae. Common.
Rubus australis. Common.
schmidelioides. Common.

Saxifragaceae.

Donatia novae-zelandiae. End Peak and Hump.
Weinmannia racemosa. Common.
Carpodetus serratus. Common.

Droseraceae.

Drosera arcturi. Hump.
binata. Lake flat.

Haloragidaceae.

Haloragis alata. Blue Cliff.
Myriophyllum pedunculatum. Hauroko outlet.
elatinoides. Hauroko outlet.
Gunnera monoica. Common.

Myrtaceae.

Metrosideros hypericifolia. Common.
lucida. Common.
Leptospermum scoparium. Common.
Myrtus pedunculata. Common.
obcordata. Common.

Onagraceae.

Epilobium nummularifolium var. pps. distinct. Hump.
nummularifolium var. *pedunculare.* End Peak.
rotundifolium. End Peak and Hump.
sp. Hauroko outlet.
Fuchsia excorticata. Common.

Umbelliferae.

Aciphylla pinnatifida (Petrie) sp. nov.* End Peak.
Lyallii. End Peak.
sp. Near lake.
Ligusticum aromaticum. Hump.
Haastii. End Peak.
Hydrocotyle tripartita. End Peak.

Araliaceae.

Panax lineare. End Peak and Hump.
simplex. Common.
arboreum. Common.
Colensoi. Common.
Pseudopanax crassifolium. Common.

Cornaceae.

Griselinia littoralis.

Rubiaceae.

Coprosma arenaria. End Peak.
rugosa. End Peak.
propinqua. End Peak and Hump.
Colensoi. End Peak and Hump.
linariifolia. Common.
Cunninghamii. End Peak.
serrulata. End Peak.
repens. End Peak.
lucida. Common.
foetidissima. Common.
rotundifolium. Common.
sp. Hump.
Nertera depressa. End Peak.
dichondraefolia. End Peak.

Compositae.

Lagenophora Forsteri. Common.
sp. Hump.
Olearia Colensoi. Hump.
nitida. End Peak bush.
Crosby-Smithiana (Petrie) sp. nov. End Peak.
Celmisia Walkeri. End Peak and Hump.
holosericea. End Peak.
discolor. End Peak and Hump.
Traversii. Hump.
coriacea. End Peak and Hump.
Petriei. End Peak.
longifolia. Common.
laricifolia. End Peak.
sessiliflora. End Peak and Hump.
argentea. End Peak and Hump.
sp. pps. distinct. Hump.
Gnaphalium luteo-album. End Peak; common.
Traversii var. *Mackayi.* Hump.
Raoulia tenuicaulis. End Peak.
sp. var. Blue Cliff.
Erechtites glabrescens. Common.
prenanthoides. Common.
Helichrysum bellidioides. End Peak.
grandiceps. End Peak.
Senecio Lyallii. End Peak and Hump.

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* Descriptions of most of new species mentioned herein will be found in the next article of this volume.

Senecio revolutus. End Peak and Hump.
elaeagnifolius. End Peak and Hump.

Stylidiaceae.

Forstera sedifolia. End Peak.
tenella. Hump.

Campanulaceae.

Pratia angulata. Common.
Isotoma fluviatilis. Outlet of lake.

Ericaceae.

Gaultheria antipoda. End Peak.
antipoda var. *depressa.* Hump.

Epacridaceae.

Pentachondra pumila.
Cyathodes acerosa. Common.
pumila.
Archera Traversii.
Dracophyllum muscoides. End Peak and Hump.
uniflorum. End Peak and Hump.
Menziesii. Hump.
longifolium. Common.

Myrsinaceae.

Myrsine Urvillei.
divaricata.

Gentianaceae.

Gentiana patula. End Peak.
corymbifera. End Peak.
flaccida (Petrie) sp. nov. Hump.

Boraginaceae.

Myosotis antarctica.

Convolvulaceae.

Dichondra brevifolia.

Scrophulariaceae.

Gratiola peruviana. End Peak.
Veronica Lyallii. End Peak.
Hectori. End Peak and Hump.
buxifolia End Peak and Hump.
salicifolia. Common both sides of lake.
Ourisia macrophylla. End Peak and Hump.
sp. End Peak.
caespitosa. End Peak.

Euphrasia australis (Petrie) sp. nov. End Peak.

Polygonaceae.

Muehlenbeckia axillaris. Common.
adpressa. End Peak.

Thymelaeaceae.

Drapetes Dieffenbachii. End Peak.
Pimelea arenaria. End Peak.
laevigata. Hump.
laevigata var. *alpina.* Hump.

Loranthaceae.

Tupeia antarctica. Common.
Loranthus Colensoi. Common.

Fagaceae.

Fagus cliffortioides. End Peak bush.
Solandri. End Peak bush.
Menziesii. End Peak bush.

Taxaceae.

Phyllocladus alpina. End Peak and Hump bushes.
trichomanoides. End Peak and Hump bushes.
Dacrydium cupressinum. Common.
laxifolium. Common.
Bidwillii. Common.
Podocarpus ferruginea. Common.
spicata. Common.
totara. Common.
Hallii. Scarce.

Orchidaceae.

Dendrobium Cunninghamii. Common.
Earina suaveolens. Common.
mucronata. Common.
Corysanthes rotundifolia. End Peak bush.
rivularis. End Peak bush.
Caladenia Lyallii. Hump.
Lyperanthus antarcticus. Hump.
Gastrodia Cunninghamii. Hump.

Liliaceae.

Astelia montana. End Peak and Hump.
nervosa. End Peak and Hump.
linearis. End Peak and Hump.

Phormium tenax. End Peak and Hump.
Cookii. End Peak.
Bulbinella Hookeri. Hump.

Juncaceae.

Juncus novae-zelandiae.

Centrolepidaceae.

Gaimardia setacea. End Peak and Hump.

Cyperaceae.

Oreobolus pectinatus. End Peak.
Scirpus sp. End Peak.
inundatus. Lake-outlet.
cernuus Hump.
Carpha alpina. End Peak.
Carex flava. End Peak.
sp. End Peak.
sp. End Peak.
sp. End Peak.
Uncinia tenella. End Peak.
sp. End Peak.
Eleocharis acuta. Hump.
acuta var. Lake-outlet.

Gramineae.

Deyeuxia Forsteri var. *humilior.* End Peak.
Forsteri var. End Peak.
Forsteri var. *pilosa.* Hump.
(= *Agrostis pilosa*). Hump.
semi-aquatic form. Lake.
Microlaena avenacea. End Peak.
Colensoi (= *Ehrharta Colensoi*). Hump.
Hierochloe redolens. End Peak.
Agrostis Dyeri. End Peak.
Deschampsia novae-zealandiae. End Peak and Hump.
caespitosa. · Hump.
Danthonia (?) *barbata* (Petrie) sp. nov. End Peak.

Filices.

Hymenophyllum rarum. End Peak and head of lake.
polyanthos. End Peak and head of lake.
pulcherrimum. End Peak and head of lake.
Hymenophyllum dilatatum. End Peak and head of lake.
demissum. End Peak and head of lake.
scabrum. End Peak and head of lake.
flabellatum. End Peak and head of lake.
rufescens. End Peak and head of lake.
unilaterale. End Peak and head of lake.
multifidum. End Peak and head of lake.
bivalve. End Peak and head of lake.
Trichomanes reniforme. Head of lake.
Cyathea medullaris. Head of lake.
Hemitelia Smithii. Head of lake.
Dicksonia squarrosa. End Peak and Hump
fibrosa. End Peak and Hump.
Davallia novae-zealandiae. End Peak and Hump.
Pteris aquilina. Common.
incisa. Common.
scaberula. Common.
Lomaria Patersoni. Both sides of lake.
discolor. Common.
vulcanica.
lanceolata.
alpina. End Peak and Hump.
capensis.
fluviatilis.
Asplenium flaccidum. Common.
bulbiferum. Common.
Aspidium aculeatum.
Polypodium pennigerum. Head of lake.
grammitidis. Common.
sp.
Billardieri.
Gleichenia Cunninghamii.
Todea superba.
hymenophylloides.
Tmesipteris Forsteri.

Lycopodiaceae.

Lycopodium fastigiatum. End Peak and Hump.
Selago. End Peak and Hump.

Art. XXX.—*Descriptions of New Native Phanerogams.*

By D. Petrie, M.A., Ph.D.

[*Read before the Auckland Institute, 22nd November, 1910.*]

Plate II.

1. Olearia Crosby-Smithiana sp. nov.

Frutex humilis, ramosa, compacta, 4–6 dcm. alta. Folia anguste linearia, 4–9 cm. longa, 2 mm. lata, marginibus forte revolutis; costa media inferiore valde prominente.

Paniculae summos ramulos versus dispositae; capitula parva, pauca, flores paucos gerentia.

A low compact shrub, 4–6 dcm. high, with numerous short erect or suberect branches, marked by the scars of fallen leaves; the higher part of the branches alone leafy.

Leaves crowded, alternate, coriaceous, acute, entire, veinless, narrow-linear, 4–9 cm. long, 2 mm. broad, shortly petioled; margins strongly revolute; upper surface with a deep longitudinal groove, more or less lacunose; under-surface marked by a stout midrib that is fringed by a delicate line of whitish tomentum; the petiole ending below in a broad thickened callosity, above which the leaves become detached.

Panicles towards the tops of the branchlets, and springing from a cluster of short acute squamiform leaves having white tomentose margins. Peduncles filiform, ± 2 cm. long, divided into 2–3 branches that are again subdivided.

Heads few, small, of few florets; involucre turbinate; scales in 2–3 series, dark brown, the lower ovate-lanceolate, the upper linear, glabrous or slightly pubescent at the tips.

Achenes very narrow, glabrous, 1 mm. long; pappus very slender, spreading, longer than the achenes.

Hab.—The Hump (3,500 ft.), south of Lake Hauroko.

I am indebted to Mr. J. Crosby Smith, F.L.S., of Invercargill, for a number of fruiting specimens of this most distinct species. The narrow-linear strongly ribbed leaves and the small slender inflorescence are very different from those of any other native species. Its nearest ally is *O. lacunosa* Hook. f. It was collected long ago at Dusky Sound by Mr. Reischek, who gave Mr. T. F. Cheeseman some pieces not in flower or fruit, and I have seen flowerless specimens from the neighbourhood of Puysegur Lighthouse.

2. Aciphylla pinnatifida sp. nov.

Caulis 15–20 cm. altus, gracilis, sulcatus. Folia 5–8 cm. longa, trifoliolata, usque ad summam vaginam divisa; segmenta linearia, pinnatisecta; pinnis linearibus, brevibus, integris, subremotis; vaginae haud in spinas laterales productae.

Stem 15–20 cm. high, slender, grooved.

Leaves numerous, radical, 5–8 cm. long, flaccid, trifoliolate, divided to the top of the sheath; segments linear, pinnatisect, the middle one

longer; pinnae linear, short, rather remote, entire, acuminate, with thickened margins and subrigid pungent tips. Sheaths short, thin, broadly obcuneate, not produced into lateral spines.

Inflorescence shorter than the culm, subflexuous, broadly ovate; bracts leaflike, with broad compressed sheaths ± 2 cm. long; the segments of the lower bracts more or less pinnatisect, those of the upper entire or slightly cut. Primary peduncles longer than the sheaths, the secondary short.

Fruits ± 3 mm. long, elliptic, 3–5 winged.

Hab.—End Peak, Lake Hauroko.

I have seen only three specimens of this very distinct plant, collected by Mr. J. Crosby Smith, F.L.S. One bears no fruit, and may be a staminate plant; the others are pistillate, but few ripe carpels are left on them.

3. **Gentiana flaccida** sp. nov.

Herba perennis, gracilis, flaccida, indivisa, erecta, ± 10 cm. alta.

Folia radicalia numerosa, 2–3 cm. longa, tenuia, obovato-spatulata, gradatim in petiolos latiores per-flaccidos lamina duplo longiores attenuata. Folia caulina radicalibus similia, petiolis brevioribus, superiora acuta in paribus oppositis disposita.

Flos terminalis, solitarius, grandis, ad 2 cm. longus.

A slender flaccid apparently perennial herb, not branched, erect, ± 10 cm. high; root rather stout.

Radical leaves numerous, 2–3 cm. long, thin, obovate-spathulate, gradually narrowed into rather broad flaccid petioles twice as long as the blades. Cauline leaves similar to the radical, but with shorter petioles or almost sessile; the upper in opposite pairs, the topmost pair acute.

Flower solitary, terminal, ± 2 cm. long. Calyx green, divided for three-quarters its length into thin linear acute lobes with an evident midrib.

Stamens as long as the calyx; pistil rather longer.

Fruit not seen.

Hab.—End Peak, Lake Hauroko.

I have seen only a single specimen of this plant, but it is so clearly distinct from any of its native congeners that I feel little hesitation in describing it. It is, of course, uncertain if the specimen I have seen represents the typical form of the plant. Its nearest ally is *G. lineata* T. Kirk, a plant that was first collected by myself on Stewart Island in 1877. The present species was collected by Mr. J. Crosby Smith, F.L.S.

4. **Euphrasia australis** sp. nov

Herba tenuis, subrigida, parce foliosa, ad 8 cm. alta, sparse pubescens, a basi ramosa; rami laterales parce subdivisi. Folia in paribus oppositis remotis disposita, suborbicularia, crassiuscula, basi subito contracta.

Flores majusculi, axillares, pedunculati, plerumque in paribus oppositis dispositi, albidi; pedunculi foliis subduplo longiores, maturi ad $1\frac{1}{2}$ cm. attinentes.

Capsula calyce persistente brevior, late obovato-cuneata.

A slender, rather rigid, sparingly leafy herb, 8 cm. high or less, sparsely pubescent with short white hairs, branched from the base, branches sparingly subdivided.

Leaves in distant opposite pairs, suborbicular, suddenly contracted into a very short petiole, rather coriaceous, apparently glabrous, recurved

at the margin, $\pm$ 6 mm. long, either side showing two broadly rounded teeth separated by a wide shallow sinus.

Flowers rather large, axillary, peduncled, generally arranged in opposite pairs; peduncles nearly twice as long as the leaves, at maturity 1½ cm long, curved.

Calyx narrow-campanulate, pubescent, divided for one-third its length into four short obtuse subcostate lobes; margins recurved. Corolla whitish, funnel-shaped, expanded at the throat; upper lip 2-lobed, lobes short, obtuse, entire: lower strongly reflexed and cut into three short obtuse entire lobes, the middle one narrower. Anthers cohering, glabrous or nearly so.

Capsule shorter than the persistent calyx, broadly obovate-cuneate, sparingly pubescent at the top.

Hab.—End Peak, Lake Hauroko.

I have not seen good specimens of this plant, which was collected by Mr. J. Crosby Smith, F.L.S., during an adventurous and laborious visit to Lake Hauroko and its neighbourhood. Owing to difficulties of travel, they are so mouldy and indifferently dried that I cannot be sure of the glabrous condition of the leaves or of the exact colour of the corolla. The species finds its nearest ally in *E. Cockayniana* Petrie, from which it differs in the suborbicular differently cut leaves, the more diffuse branching, and the elongated curved peduncles.

5. Euphrasia umbellata sp. nov.

Herba annua, ramosa, gracillima, glabra. Caulis gracilis, 1½–2 cm. longus, deinde umbellato-ramosus; rami gracillimi, patentes v. ascendentes, 5–10 cm. longi, parce subdivisi.

Folia in paribus oppositis subdistantibus disposita, viridia, tenuia, trinervia, anguste cuneata, ad apicem in 5–7 breves subulatos subacutos dentes secta.

Flores solitarii, longe pedunculati: corolla per-anguste infundibuliformis, 1–1½ cm. longa, recta: stamina glabra.

A low delicate much-branched glabrous annual herb.

Main stem very slender, 1½–2 cm. long, then umbellately divided into 4–7 spreading or ascending filiform branches 6–10 cm. long that are again sparingly subdivided; branches not creeping or rooting.

Leaves in rather distant opposite pairs, greenish when dry, sessile, thin, not recurved, 4–6 mm. long, 2 mm. broad, narrow-cuneate in outline, entire for two-thirds their length, the upper third cut into 5–7 narrow subacute subulate lobes.

Flowers solitary in the axils of the upper leaves, not in opposite pairs, long-peduncled; peduncles capillary, 1–1½ cm. long, straight, calyx short, tumidly campanulate, cut into four short subulate teeth. Corolla 1 cm. long, very narrow funnel-shaped, straight; the lips short: anthers glabrous or nearly so.

Capsule (unripe) apparently shorter than the tube of the calyx.

Hab.—Mouth of Oreti River, Southland.

In common with the preceding species described in this paper, the present plant was collected by Mr. J. Crosby Smith, F.L.S. His zealous and fortunate collecting is revealing in the south-western region of the South Island a more distinctive and varied flora than has hitherto been supposed to occur there. The Fiord County, with its many high ranges of

Muehlenbeckia Astoni Petrie.

hills, is especially worthy of exploration, but difficulties of travel have made it almost impracticable. Now that these difficulties are being in part removed, our knowledge of the alpine plants of the region must steadily improve, and to Mr. Crosby Smith and his fellow-workers in the South we must look for a fuller knowledge of them.

In addition to the new species enumerated above, Mr. Crosby Smith has found *Celmisia Traversii* Hook. f. on End Peak (Princess Range), at Lake Hauroko, a most unexpected extension of the range of that well-marked species, and in keeping with his former discovery of *Stellaria Roughii* Hook. f. on the Takitimu Mountains.

6. Muehlenbeckia Astoni sp. nov.

Frutex erectus, ad 15 dcm. altus, caules complures lignosos, rectos, teretes, brunneos, transversim $\pm$ 8 mm. latos emittens; tertia caulis parte summa tantummodo ramosa, ramis multitoties in ramulos tenues, flexuosos, leves, brunneos, divaricantes et intricate implicatos divisus, internodiis brevibus.

Folia parva, pauca, terna v. bina in ramulis lateralibus valde decurtatis insita, magnitudine variabilia, 3–9 mm. lata, paene aeque longa, plerumque late obcordato-cuneata, tenuia, glabra, integra, apice late incisa; petiolis gracillimis, laminas fere aequantibus.

Flores minuti, subglomerati, unisexuales (ut videtur), in extremis ramulis lateralibus foliosis insiti.

Fructum haud vidi.

An erect shrub, reaching a height of 15 dcm., and consisting of a number of straight dark-brown glabrous wrinkled canelike woody shoots, $\pm$ 8 mm. across; unbranched below, at three-quarters their height branching and repeatedly subdividing into very numerous slender flexuous divaricating and interlacing branchlets with short internodes; the main middle shoot generally overtopping the lateral ones.

Leaves in twos or threes on short arrested side shoots, small, few, very variable in size but not in outline, 3–9 mm. broad and about as long, glabrous, thin, entire, broadly notched at the apex, widely obcordate-cuneate or with the base rather rounded, on very slender petioles that equal or exceed the blades; veins very obscure.

Flowers minute, apparently unisexual, in small fascicles at the tips of the arrested leafy lateral shoots. Peduncles short, very slender, rarely almost obsolete.

Ripe fruit not seen.

Hab.—Palliser Bay, near Orongorongo, and Wainuiomata. Collected by Mr. B. C. Aston, who informs me that the plant is of rare occurrence.

This species is a near ally of *M. complexa* Meissn. The stout erect woody canelike shoots, the divaricate and interlacing habit of branching, and the thin small obcordate-cuneate leaves clearly mark it off as distinct. Fresh specimens must be studied to ascertain the characters of the flowers and fruit. Owing to the entanglement of the twigs and their flexuous form it is difficult to make satisfactory dried specimens, as the leaves and flowers cannot be directly subjected to pressure, so that they are very apt to curl and fall off.

Art. XXXI.—*The Igneous Rocks of the Waihi Goldfield.*

By P. G. Morgan, M.A.

[*Read before the Wellington Philosophical Society, 5th October, 1910.*]

Contents.

Introduction.

In leisure time during the years 1903–5 the writer was engaged in making a petrographical study of the rocks occurring in or near the Waihi Goldfield. The main object of this study was to obtain data that would be of value in a detailed investigation of the geology and the mineral veins of that district. It was thought that such an investigation would assist in defining the limits of the auriferous rocks, and in discovering the mode of origin of the veins and the source of their metalliferous constituents. More especially it was hoped that clues to the laws regulating the distribution of values in the auriferous veins and the depth to which payable ore might be expected to persist would be found.

In this work the writer was interrupted by a change of residence and occupation. So far as his researches went, the possibility of data of high economic value being obtained by close petrographical study, by chemical analysis, and by other methods of scientific investigation was clearly indicated. Since the study as originally planned by the writer remains woefully incomplete, it is not possible to set forth all that might be accomplished by scientific work, nor is it advisable to state various conclusions that are not fairly well supported by the evidence actually obtained.

The object of the present paper is to put on record the main results of the writer's petrographical work, with such descriptions as may be useful to future workers. It is desired especially to direct attention to the nature of the rocks enclosing the veins of the Waihi Mine, and to the type of alteration that these rocks have undergone.

Outline of Geology.

The oldest rocks exposed in the neighbourhood of Waihi are the altered lavas in which the gold-bearing lodes of the Waihi, Grand Junction, and other mines occur. These rocks are very generally considered to be quartz-bearing andesites and dacites, although a few years ago, when various samples from the Waihi mines were determined by Professor W. J. Sollas as altered pyroxene-rhyolites, some doubt as to their true nature arose.

The term "auriferous series" may be applied to the rocks in question as a non-committal name with respect to their petrographical character. There is as yet no very positive evidence available concerning the age of the auriferous series, but it may be assumed as Eocene, or possibly early Miocene.

After the rocks of the auriferous series had been subjected to more or less denudation, and very probably to the internal change known as propylization, a limited amount of material accumulated in valleys or other hollows that were doubtless occupied by lakes. Such material, in the form of well-stratified tuff, is exposed in the Grand Junction A or No. 1 shaft at a depth of 620–640 ft. below the surface, and about 240 ft. below present sea-level.

Soon volcanic activity on a large scale was resumed, and a second great outpouring of andesitic lavas took place. These rocks form high hills to the north of Waihi, and appear on the surface in the open valley west of Martha Hill. They also occur to an unknown extent under the younger rhyolitic rocks at and near Waihi. In point of age these younger andesites and their accompanying tuffs (developed only very slightly near Waihi) may be referred to the Beeson's Island group of McKay, or to Fraser's "Tertiary Volcanic Rocks of the Second Period." To the Beeson's Island group may also be assigned the great development of tuffs, in places much intersected by dykes, seen along the coast east and north-east of Waihi.

After the eruption of the "Second Period" volcanics a comparatively brief period of rest from igneous activities was followed by the outpouring of acid lavas. Some of these were rhyolites of the peculiar brecciated-looking type known as "wilsonite" (11,* vol. 1, pp. 123, 124; vol. 2, pp. 46, 138). This rock forms the greater part of the so-called "Waihi Plains," and wraps partly round the outcrops of the auriferous series. With it are associated small amounts of tuff.

Between Waihi and the coast there appear spherulitic rhyolites, probably of approximately the same age as the wilsonite, but possibly older. These are well developed east and north-east of Waihi. They are seen on the coast north of Houmunga Bay, at Waihi Beach (where they contain auriferous veins), and at Mount Hikurangi, a conspicuous elevation a few miles south of Waihi.

Breaking through the wilsonite in various places, and therefore of younger age, are light-coloured rhyolites of harsh texture. These are observable mainly in and near the Town of Waihi, and are also well seen near Waikino, four miles to the west.

The various rhyolites may be provisionally regarded as of Pliocene age, and as contemporaneous with the great rhyolitic flows of the central part of the North Island.

Some hornblende-andesites that occur near Waihi are younger than any of the other andesites, but their age with reference to the rhyolites is uncertain.

The recent surface accumulations of the Waihi district, consisting of a little conglomerate, talus, clay, &c., are of little moment from a purely geologic point of view. The loamy clay on the slopes of the Martha Hill is apparently largely of aerial origin, and might therefore be called loess. Since this material furnishes a cheap and efficient "filling" for the Waihi Mine workings it has considerable economic value.

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* This and other numbers similarly inserted in brackets refer to list of literature at end.

Previous Petrographic Descriptions.

In 1870 Sir James Hector (1) passed through the Waihi district. Apparently he considered the andesitic rocks of the neighbourhood to be of doleritic and basaltic character. On the Waihi Plains he noted the presence of " trachyte " [? wilsonite]. To the eastward Hector observed hills capped by " true rhyolite " or " quartzose trachyte " [spherulitic rhyolite with quartz phenocrysts], and on the coast-line cliffs of " true trachyte agglomerate."

In 1882 Mr. S. H. Cox (2), now Professor of Mining in the Royal College of Science and Technology, London, made a flying survey of the Ohinemuri Goldfield. Cox mapped the rocks near Waihi as " tufaceous sandstone" [propylitic facies of andesites and dacites], dioritic rock, anamesite (?), and rhyolite.

About 1883 the late Professor G. H. F. Ulrich determined by microscopic study the andesitic nature of the gold-bearing rocks of the Thames district. Ulrich's work, though known only through a communication made to Professor F. W. Hutton (3, p. 19) may be regarded as the most important contribution ever made to New Zealand petrography. Henceforward the auriferous rocks at Waihi and in other parts of the Hauraki Goldfield if resembling those at Thames were regarded as altered or decomposed andesites—an essentially correct conclusion.

In 1897 Professor James Park, apparently on the strength of microscopic examinations specially made by Ulrich (3, pp. 27, 28) referred to the rocks of the Waihi auriferous series as propylite resulting from the alteration of hypersthene-augite-andesite (3, pp. 26, 87).

It ought to be remarked that the two rock-specimens determined by Ulrich were probably both from the andesitic rocks overlying the auriferous series, and hence Park's determination of the latter as altered hypersthene-augite-andesite can hardly be regarded as authoritative. Apparently this writer at that time regarded the Waihi andesites as all of one type and of one geological age.

Park described the other volcanic rocks at Waihi as rhyolites, of which he mentioned there were at least two distinct flows.

In the same year as the publication last cited an important report on the geology of the Cape Colville Peninsula appeared from the pen of Mr. Alexander McKay (4). On page 59 are a few sentences referring to the auriferous rocks in the neighbourhood of Waihi. These are placed in the " Kapanga group," but, evidently by design, no specific rock-names are given. In the absence of proper microscopic determinations McKay's attitude of reserve may be regarded as being highly correct. The various rhyolites near Waihi are described (pp. 67, 68) as " spherulitic rhyolite," " a remarkable brecciated rhyolite " (wilsonite), and " an earthy compact rhyolite."

Largely as a result of the boom in gold-mining that prevailed during the years 1895–97, a number of papers in which the nature of the rocks at Waihi was more or less cursorily mentioned made their appearance, but for the purpose of the present article it is not necessary further to mention these publications, which were nearly all of an ephemeral character.

In 1899 the late Mr. F. Rutley, in association with Professor Park (5), described several rhyolites from the neighbourhood of Waihi, as well as a doubtful silicified rock, a supposed silicified andesite tuff, and a supposed silicified andesite. Rutley was the first to observe tridymite in the rhyolites

of Waihi and other parts of the Hauraki goldfields. His work on the silicified rocks plainly pointed the way to a theory of metasomatic replacement of country* by vein-material.

The next year Park (6) described a hypersthene-andesite stated to be from the 300 ft. level (probably No. 3 or 279 ft. level) of the Waihi Mine. He noted as original minerals plagioclase, some (probable) orthoclase, hypersthene (much decomposed), a little enstatite, a little possible augite, some magnetite, and perhaps quartz. The possible presence of original hornblende (indicated by lozenge-shaped spaces crowded with dark dust) was also observed. Secondary minerals were magnetite, haematite, serpentinous matter, calcite, and quartz.

Park's determination of orthoclase in this, perhaps the first specimen of rock from the Waihi Mine ever microscopically examined, is noteworthy, but, as will be shown on later pages, the primary origin of much or perhaps of all the orthoclase in Waihi andesites and dacites may be strongly questioned.

In 1902 the writer, without having made any microscopic examinations, but relying on the statements of previous observers and on the results of analyses made by himself and others, stated that "the Waihi reefs lie in a decomposed andesite or propylite, which there is some reason to believe is older than the bush-clad andesite of the hills to the north and west." This latter is "of a different character to that forming the [Martha] hill itself" (7, p. 165).

Two years later, the writer, having examined a number of sections of Waihi rocks, incidentally mentions that the "country" in which the lodes occur is "decomposed quartz-andesite" (8, p. 429).

In 1905 Mr. Waldemar Lindgren, the well-known economic geologist, made a visit to Waihi. In a subsequent article on the Hauraki goldfields (9) Lindgren states, "Mr. Park determines it [the country of the Waihi Mine] on authority of Mr. Hutton [? Professor Ulrich] as hypersthene-andesite; all of it, however, is not of that character, for specimens collected on the 500 ft. level† in the footwall of the Martha lode consist of a dark-green porphyritic rock with recognisable phenocrysts of corroded quartz and orthoclase. The ferro-magnesian silicates, probably pyroxene, are altered to serpentinoid aggregates. Lime-soda feldspars could not be definitely recognized, while the groundmass is micropoikilitic, and certainly contains much quartz. The rock is thus either a dacite or is intermediate between a dacite and a quartz-bearing trachyte."

Lindgren also says, "The rock adjoining the sulphide ore [at the 500 ft. level, Martha lode] has suffered great alteration, although seemingly fresh. Pyrite and a carbonate, probably calcite, are abundant in metasomatic development, as is a brownish-green serpentine. The veinlets traversing it contain much secondary orthoclase or valencianite, together with quartz and calcite."

A letter written by the writer commenting on Lindgren's article remarks that the lode-bearing rock at Waihi "might perhaps be more correctly called quartz-andesite or dacite" (10, p. 861).

In 1905 and 1906 appeared "The Rocks of Cape Colville Peninsula, Auckland, New Zealand" (11). In this important work, consisting of

* The term "country rock," now so commonly employed by writers on economic geology, is, strictly speaking, tautological. The miners of the Hauraki Goldfield, as a rule, employ the more correct expression, "country."

† Probably the No. 6 or 555 ft. level.

petrographical descriptions by Professor W. J. Sollas, with additional matter and micro-photographs by Mr. Alexander McKay, nine rocks from Waihi mines are described. Of these, one is classed as a doubtful andesite, two as pyroxene-rhyolites or andesites, five as rhyolites (mostly pyroxene-rhyolites), and one is called "a much-decomposed altered quartz-feldspar-pyroxene rock." This last rock may possibly belong to the andesites overlying the auriferous series.

Sollas also describes various andesites and rhyolites from the neighbourhood of Waihi. Reference will be made to some of his descriptions on a later page.

In 1908 Dr. J. M. Bell and Mr. Colin Fraser, in an article on the Waihi Mine (12), refer to the mine-rocks as altered dacites, containing stringers of calcite, quartz (both chalcedonic and highly crystalline), orthoclase (variety valencianite) in minor amount, and pyrite. They remark, "The vein-bearing rocks have been described as rhyolites, but careful chemical and petrographical investigation have led the writers of the present paper to classify them as dacites" (12, p. 388).

In the same paper reference is made to the younger andesitic and dacitic lavas and tuffs that overlie the vein-bearing dacites. Three types of rhyolite—namely, (a) spherulitic rhyolite, (b) pumiceous brecciated flow rhyolite ("wilsonite"), and (c) grey lithoidal rhyolite—are recognized.

Dr. J. Malcolm Maclaren, who is well acquainted with the Hauraki goldfields, has also questioned Sollas's determination of the country in the Waihi Mine as a "hornblende-pyroxene-rhyolite." After quoting Sollas's description (11, vol. 2, pp. 67, 68). Maclaren remarks, "In view of the occurrence of orthoclase (valencianite) in the lodes of Waihi, and of the exceedingly altered state of the country, it is conceivable that the orthoclase found in the above rock may be valencianite due to secondary action; indeed, considerable indication of such a growth is outlined in the foregoing petrological description [Sollas's]. It is therefore probable that the highly decomposed rocks of the Waihi area do not represent original rhyolites, but a local succession of andesites, dacites, and even more acid rocks that have been so thoroughly altered by solfataric solutions that many of their original characters have disappeared" (13, p. 315).

In 1909 Mr. A. M. Finlayson, in an article entitled "Problems in the Geology of the Hauraki Goldfields, New Zealand" (14), remarks on the occurrence of valencianite (adularia) as a secondary product in the completely altered rocks of Waihi. He isolated and analyzed the mineral, with the following results:—

SiO_2	65·85
Al_2O_3	18·48
K_2O	11·25
Na_2O	4·11
	99·69
Specific gravity	2·61

Finlayson says, "In view of the fact that this orthoclase is, in the specimens examined, of secondary origin, while the primary feldspars are soda-lime varieties, the original rocks appear to have been in the main andesites and dacites. . . . The presence of soda in the Waihi

valencianite is doubtless due to its derivation from soda-feldspars by the action of the potash-bearing vein-solutions" (14, pp. 634–35).

Finlayson also made a series of instructive analyses of specimens, all except one of which were from a crosscut to the Empire vein at the 850 ft. level of the Waihi Mine. These analyses show clearly the transition from "chloritized hornblende-dacite," with 58·39 per cent. of silica, to "altered dacite," with 61·78, 69·35, and 76·61 per cent. of silica, and finally to "replacement ore," with 85·65 per cent. of silica.

In his latest work Professor Park refers to the rocks of the Waihi Goldfield in much the same terms as in 1897. The auriferous rocks are called "altered andesites and dacites" (15, p. 349).

In a recent paper, entitled "The Waihi Goldfield" (16), Dr. J. M. Bell mentions the Waihi rocks by the same names as in the previous article by himself and Mr. C. Fraser (12).

SPECIAL PETROGRAPHY.

From February, 1903, to May, 1905, the writer made and microscopically examined a large number of sections from specimens of rocks occurring in or near the Waihi district. These will be described and discussed under the following headings:—

(1.) Rocks of the auriferous series.
(2.) Stratified tuff of the Grand Junction shaft.
(3.) Andesites and tuffs of the "Second Period."
(4.) Rhyolites.
(5.) Andesitic rocks of doubtful age.

(1.) *Rocks of the Auriferous Series.*

(*a.*) *Quartz-andesites and Dacites.*

The specimens from which sections were made are for the most part from Nos. 5 and 6 levels* of the Waihi Mine. These levels correspond to depths below the surface of 445 ft. and 555 ft. respectively as measured from the collar of No. 1 shaft. Three or four are from higher levels of the Waihi Mine, and a few come from the Grand Junction and Waihi Extended Mines at depths of approximately 480 ft. to 500 ft. below the surface.

Macroscopically the specimens are generally dark-grey or greenish close-grained rocks, showing porphyritic feldspars of moderate size and a few phenocrysts of glassy quartz. Numerous dark altered crystals are referable to pyroxenic or amphibolic minerals. A marked effervescence with cold dilute hydrochloric acid in practically all specimens indicates the presence of calcite.

Under the microscope most sections exhibit many crystals of moderately or well twinned plagioclase which by the extinction angles and relative indices of refraction as compared with other minerals and with Canada balsam are shown to be mostly acid labradorite. Andesine is present in many cases. The twinning is nearly always on the albite law: pericline twinning is somewhat rarely seen. Zonary banding, pointing to a difference in the composition of individual crystals, is quite common. Nearly universally, if not always so, the more acid feldspar (usually near andesine) is on the outside.

* These are the numbers given in published plans and reports; at the mine itself the practice is, or was, to call these levels Nos. 6 and 7.

As regards alteration, the plagioclases vary from quite fresh individuals showing good twinning to highly decomposed crystals in which the original twinning has all but disappeared, and is indicated only by a faint banding in portions of the crystals.* From these it would seem but a small step to the highly altered feldspars without a trace of twinning that are commonly present. The alteration-products are largely calcite and quartz. Some muscovite is occasionally present in small flakes, and in odd instances haematite fills the cleavage-cracks. The most-altered plagioclases (those with just a trace of repeated twinning) show a mosaic which is mainly secondary quartz and feldspar. The exact nature of the latter is not always apparent, but in some cases it can be determined as valencianite. In one instance where a microscopic vein of quartz and calcite crosses a section valencianite may be observed replacing a crystal of plagioclase intersected by the vein.

Nearly all the sections have feldspar crystals that by their optical properties appear to be orthoclase. These are in some instances fresh, and show Carlsbad twinning. One such crystal, with extinction angles of $19\frac{1}{4}°$ and $19\frac{3}{4}°$, has one half slightly but decidedly zonary. Many of the orthoclases, however, are much altered, and consist mainly of a mosaic of quartz and calcite, with some muscovite, iron-oxide, &c. The apparently residual feldspar in many cases suggests valencianite, but to prove decisively that it is really secondary is no easy matter. A consideration, however, of the manner in which transition forms occur between undoubted plagioclase and the crystals in question leads to the conclusion that the latter must represent highly altered lime-soda feldspars. In this connection the almost invariable presence of calcite is strongly suggestive of an original lime-content.

Original quartz grains are present in all the sections. Some sections have only one or two small quartz grains, others have several comparatively large phenocrysts. All the quartz grains have rounded outlines, in many instances with deep bays, and thus show clearly the effects of corrosion by a fluid magma. Very rarely can an approach to bi-pyramidal outlines be seen. Occasionally the grains of quartz seem to include small rounded patches of the groundmass, but these are probably all, or nearly all, embayments cut across in the sectioning.

Ferro-magnesian minerals are represented by fairly numerous phenocrysts, generally entirely altered to chlorite, serpentinous matter, iron-oxides, &c. In a few sections augite is quite recognisable. Hypersthene or similar rhombic pyroxene seems to have been originally present in every section. Hornblende is probably represented in odd sections by dark lozenge-shaped masses similar to those described by Park (6, p. 343).

The other original minerals present call for little description. Small crystals or grains of magnetite are always seen. Some of these, however, are presumably due to the decomposition of ferro-magnesian minerals. The magnetite is often partly altered to a leucoxenic-looking mineral, but this, according to Finlayson, is probably siderite. Apatite can usually be distinguished as small needles in the feldspars. Zircon is possibly present in one or two sections.

The groundmass in the various sections varies considerably in amount, but may be said to form much more than half the rock, as a rule. In the

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* Sollas speaks of similar feldspars as showing traces of microperthitic structure (11, vol. 2, pp. 18, 54).

fresher examples an abundance of small feldspar laths crowded together in more or less parallel arrangement is present, and thus the structure is decidedly inclined to be pilotaxitic; but, since calcite and other alteration-products are invariably present to some extent, the original pilotaxitic (or possibly hyalopilitic) structure is partly obscured. More commonly the groundmass consists mainly of a granular mosaic of quartz, feldspar, and calcite, with minor amounts of other minerals.

(b.) *Wall-rocks.*

The rocks now to be discussed are from the same localities as those coming under (*a*), except that, as indicated by the heading, the specimens examined were obtained either within a few feet of the larger veins or were taken from the actual walls of the veins.

Macroscopically the wall-rocks are evidently more highly altered than those some distance from the veins. They are lighter-coloured, and do not effervesce so freely with hydrochloric acid. Feldspar and, less commonly, quartz phenocrysts may be observed. Ferro-magnesian minerals, while usually distinguishable, are always intensely affected by decomposition.

Under the microscope the sections show extreme alteration. The feldspar phenocrysts are nearly all so decomposed that the identification of their original character becomes uncertain. In one or two sections fairly fresh binary twins of orthoclase may be recognized. In most of the sections there are feldspars showing traces of repeated albite twinning, and hence it may be concluded that these feldspars were originally plagioclase. In the main, however, albite twinning is absent, and, since the refractive index of any recognizable feldspar is well below that of Canada balsam, the mineral approaches orthoclase or anorthoclase in its characters. The most highly altered feldspars consist of a mosaic of quartz and feldspar, with minor quantities of calcite and " kaolinitic " matter. In some cases the feldspar of the mosaic is evidently secondary, and therefore to be termed " valencianite." In other instances, however, its secondary nature is less certain, though appearances are generally quite consistent with such a conclusion. The so-called " kaolinitic " matter mentioned above is strongly suspected to be near sericite in composition, but in the absence of chemical tests its exact nature seems indeterminable.

Original quartz grains appear exactly as in the rocks coming under the last heading, except that they are in some instances in optical continuity with clearly secondary quartz, a phenomenon not observed in the less-altered country.

The ferro-magnesian minerals are entirely altered to chloritic material, with a little iron oxide, &c., so that the original species can hardly be more than guessed at. Rhombic pyroxene may perhaps be assumed as having been present. Primary hornblende is doubtfully indicated by the presence of many small magnetite grains in some of the chloritic matter which has outlines possibly referable to amphibole.

Other original minerals include a little magnetite, often with leucoxene-like alteration (? to siderite). and a few small needles of apatite. A section made from a diamond-drill core obtained in the Grand Junction Mine at a depth of nearly 800 ft. from the surface shows a nest of some mineral with the appearance of tridymite.

The groundmass in the sections of wall-rocks is a granular mosaic composed largely of quartz, with probably more or less valencianite, a little

calcite, &c. An almost opaque streaky substance, nearly white by reflected light, forms much of the groundmass. Such material is often referred to as "kaolinitic," but, as previously remarked, is probably near sericite in composition.

Of secondary minerals not already mentioned, pyrite, almost invariably in small cubes, is the most conspicuous. Epidote or allied mineral may very rarely be present.

(c.) *Vein-material.*

The vein-material of the Waihi mines largely replaces country, and therefore will be discussed to some extent. In the upper levels of the Waihi Mine the vein-material is quartz, with a little clay, iron and manganese oxides, &c. Some of the quartz is crystalline to the eye, and has obviously been deposited in open spaces. Much, however, is of flinty or chalcedonic appearance. Sections of this chalcedonic material show that it is mainly an indefinite kind of mosaic that resembles the quartz mosaic seen in highly altered wall-rock, and it therefore suggests replacement or silicification of country. This view is supported by a study of the ore from lower levels. The following analysis* of a representative piece of "oxidized" ore from one of the upper levels shows that the material is far from being pure quartz :—

SiO_2	89·98
Al_2O_3	1·82
Fe_2O_3 (including FeO calculated to Fe_2O_3) ..	5·62
MnO and NiO	0·39
H_2O at 100° C.	0·26
Loss on ignition	1·60
	99·67

Gold, 2 oz. 5 dwt. 17 gr. per ton. Silver, 10 oz. 2 dwt. 12 gr. per ton.

Sections made from a portion of the specimen that furnished the material for the above analysis show ore with replacement characters seamed by tiny veins of crystalline quartz.

In Nos. 5 and 6 levels (445 ft. and 555 ft.) of the Waihi Mine the presence of partly unsilicified country in the veins is easily recognized. In places quite a large proportion of the vein-material is dark-coloured rock, which in some instances is actually less altered than the wall-rock.

Sections of the less-silicified rock from the veins are very like those of the wall-rocks. Feldspar is the chief original mineral recognizable. Some individuals with feldspathic outlines are mosaics of quartz and presumably secondary orthoclase or anorthoclase, together with more or less kaolinitic, or more probably sericitic, material. In places fresh, easily recognized valencianite with good cleavage and low index of refraction occurs. Binary twins of apparent orthoclase are observable in at least one section. In several slides traces of repeated albite twinning are quite distinguishable in the feldspars, and in one section acid labradorite, and perhaps andesine, can be identified. Some original quartz in rounded grains is present in all the slides. Ferro-magnesian minerals are in general even more altered than in the wall-rocks, and are represented by somewhat indefinite masses of chlorite and other minerals, particularly pyrite, so that the original species

* See 7, p. 182.

cannot be ascertained. The groundmass is more or less a quartz mosaic. Other minerals present in it are magnetite, pyrite, and calcite.

(*d.*) *Discussion of Nomenclature.*

With the notable exceptions of Sollas, and to some extent of Lindgren, the various writers who have been quoted on previous pages substantially agree in describing the rocks of the auriferous series as andesites, quartz-andesites, or dacites. Lindgren hesitates between dacite and quartz-trachyte as a name for these rocks; but this geologist examined wall-rock from the Waihi Mine only. It would also seem to be the case that all, or nearly all, Sollas's determinations were made from samples of highly altered rock adjoining large veins. Had Sollas been given an opportunity of examining a series of less-altered specimens taken some distance from the larger ore-bodies it is probable that he would have reached conclusions more in agreement with those of New Zealand workers.* As matters stand, however, the presence of much apparent orthoclase has given rise to a difficulty in naming the auriferous rocks.

From the petrographical descriptions given on the preceding pages it will be gathered that there is much evidence for the view that most, if not all, of the supposed original orthoclase is of a secondary character, replacing original lime-soda feldspar, as has already been suggested by Maclaren and Finlayson. Thus the determination of the auriferous rocks as quartz-andesites or dacites (these terms being here used as all but identical in meaning) may be regarded as proved. at least as regards the Nos. 3, 4, 5, and 6 levels (279 ft., 353 ft., 445 ft., and 555 ft.) of the Waihi Mine, the 500 ft. level of the Waihi Extended Mine, and the 494 ft. level of the Grand Junction Mine. There is no reason for supposing that the rocks of the Waihi-Union and Waihi-Silverton Mines are of different character. Samples of the less-altered country from all the Waihi mines show a great similarity, so that they are possibly all of one original type—probably a hypersthene-dacite with some augite and perhaps a little hornblende.

Chemical analyses of the less-altered mine-rocks entirely support their determination as dacites of a somewhat basic type. The analyses known to the writer show a silica-content ranging from 55 to 61 per cent., with other constituents in proportions normal to an ordinary andesite or dacite that has been somewhat affected by solutions containing carbon-dioxide. The following determinations of silica and water made on rocks from the present lowest level of the Waihi Mine, communicated to the writer by Mr. A. H. V. Morgan, M.A., Director of the Waihi School of Mines, show that the rocks at that level are, if anything, less acidic than in the upper levels :—

	Moisture lost at 100° C.	SiO_2.
I	2·30	55·13
II	1·80	56·23

I, country in crosscut at 1,000 ft. level towards Royal reef, about 50 ft. from No. 5 shaft; II, country in crosscut at 1,000 ft. level from No. 5 shaft, about 50 ft. south of No. 4 shaft.

* Sollas, however, regarded some of the rocks he examined as possibly andesites, and his descriptions of specimens 3/2719 and 4/2721 (11, vol. 1, pp. 128–50) may be cited as evidence that he was inclined to call rocks similar to those from the Waihi mines altered dacites or andesites.

(e.) Alteration of Vein-bearing Dacites.

From the preceding pages it will be gathered that near the quartz lodes the dacites are partly silicified, especially in the groundmass. The original lime-soda feldspars have been almost entirely replaced by valencianite, quartz, probable sericite, and other minerals. Chloritization of the ferro-magnesian constituents is prominent. In the sulphide-ore zone more or less pyrite is present.

At some distance from the veins chloritization of the ferro-magnesian minerals is perhaps the most noticeable feature. Many, but not all, of the lime-soda feldspars appear to be replaced by valencianite. Calcite as a secondary mineral is more abundant than in the wall-rocks. Other secondary minerals are quartz, a little pyrite, and perhaps some muscovite and sericite.

By the changes outlined in the last paragraph what may be called the propylitic facies is brought about. The name "propylite" for such rocks, as used by Park and others, is a most convenient term that undoubtedly fills a want, and it is therefore to be regretted that the usage is open to the objection that the name was originally intended to indicate a distinct rock species.

Further discussion of the nature of the orthoclastic feldspar of the altered dacites seems desirable. Some is clearly secondary, and is therefore valencianite. Finlayson has shown that this valencianite is a soda-orthoclase or anorthoclase (14, p. 634). Much more abundant, however, are altered feldspar crystals, now consisting partly of untwinned feldspar of low refractive index, partly of quartz, calcite, and other minerals. Reasons for believing that the feldspar in these crystals is not the remains of the original mineral, but is an alkali (potash-soda) feldspar of secondary character, are the following:—

(1.) In many sections evident transitions from lime-soda feldspars to purely alkali feldspars may be seen.

(2.) The nearer the lodes, the less the number of recognizable lime-soda feldspars, and the greater the number of alkali feldspars.

(3.) Chemical analyses show comparatively low percentages of silica and potash in the altered dacites when 30 ft. or more from any large lode.

(4.) The alkali feldspars usually contain as a decomposition-product calcite, and therefore the presence of lime in the original feldspar is indicated.

Of the highly altered feldspars, it cannot be asserted that all were originally lime-soda feldspars, but it seems certain that at least the majority were such. There may, however, be reason for thinking that the fresh but rarely seen individuals of apparently pure potash feldspar with binary twinning are primary. It would be difficult to prove the contrary.

If the possibility that some of the alkali feldspar is original be admitted, then it may be supposed either that orthoclase was a constituent of the original andesitic or dacitic magma, or that during or immediately preceding eruption there was some mixing of an andesitic magma with a rhyolitic differentiate. The presence of corroded quartz seems to support the latter hypothesis, which is decidedly an attractive one, however slender a foundation it may rest upon.

(f.) Significance of Propylitic Facies.

It may be asked whether the propylitic facies, as developed at Waihi, does not necessarily involve the formation of secondary alkali feldspar

replacing lime-soda feldspar. It cannot be doubted that such a change has taken place to some extent in the rocks some distance from the veins, but more especially in the wall-rocks. The chief agents in ordinary propylization are without much doubt carbon-dioxide and water, and at Waihi a considerable amount of potash appears to have been introduced when propylization took place, so that a propylitic facies, which is possibly somewhat unusual,* was brought about.

The appearance of the propylitic facies seems closely connected in some way with ultimate silicification in the neighbourhood of planes of fracture—that is to say, with vein-formation. The concentration of metallic minerals, and more especially of gold and silver in the veins, gives a high economic value to any successful attempt to explain the various phenomena attending vein-formation and the localization of ore-shoots and bonanzas. It seems certain that vein-formation in propylitic rocks is due to ascending solutions, which also are presumably the carriers of metallic minerals, and yet in the Hauraki Goldfield the influence of the country on the localization of values is enormous. As the basis of a working hypothesis, it may be suggested that, in effect, a double circulation was set up by some unknown factor or factors; whilst carbon-dioxide and potash in aqueous solution made their way hundreds of feet from the vein-fractures, other substances from the country entered the veins, and probably caused or aided the precipitation of gold, silver, and other metals. Osmosis and electro-chemical agencies may well be supposed to have been concerned in the double circulation thus invoked. It is wished, however, rather to emphasize the conception that there was interaction between the whole body of propylitic rock and the ascending vein-forming solutions during the period of propylization. In other words, propylization and vein-formation were contemporaneous and to a great extent interdependent.

Problems to be solved at Waihi and elsewhere are: What are the conditions necessary to propylization? Does the propylitic alteration immediately succeed the extrusion and solidification of dacitic or andesitic lavas, or does it take place at a later date? Is it a long-continued or a rapid process? Again, does vein-formation accompany propylization as a more or less necessary concomitant, or does it simply follow mainly because rocks with the propylitic facies afford better facilities in some way for vein-formation? The economic geologist will be further interested to learn, if possible, why quartz veins in propylitic rocks more often contain appreciable quantities of gold and silver than quartz veins in other classes of rocks.

The discovery of the laws regulating the distribution of ore-shoots and bonanzas in the quartz veins of the Hauraki goldfields probably depends in great measure upon the scientific investigation not only of the ore-bodies themselves, but of the enclosing rocks. It has been said by many persons—some with a sound practical knowledge of mining in the Hauraki goldfields—that it is impossible to discover such laws; but the progress made in economic geology during the past twenty years gives hope that rules possessing real value may yet be formulated.

(2.) *Stratified Tuff of the Grand Junction Shaft.*

At a depth of about 620 ft. the Grand Junction A or No. 1 shaft passes from andesite into fine-grained volcanic *débris* or tuff, which at 630 ft. to

* A similar facies is developed at Karangahake, and possibly elsewhere in the Hauraki Peninsula.

640 ft. is in well-marked layers with a dip of 21° to 22° to the southward. At some depth not exactly ascertained by the writer this shaft enters the older rocks of the auriferous series.

Pieces of much-altered wood still retaining about 10 per cent. of carbon were common in the material excavated from the shaft at 620 ft. to 630 ft., or thereabouts. These, evidently derived from shrubs or small trees, averaged less than 1 in. in diameter, and were in no case more than a few inches long. Sections made of the enclosing tuff show its fragmentary character very well, especially by reflected light. The constituents appear to be mainly highly decomposed broken feldspar crystals, with a few grains of quartz and other minerals. The secondary products present are calcite, chlorite, pyrite, and nearly opaque kaolinitic matter (probably mainly sericite).

The well-stratified tuff at 630 ft. appears to have suffered but little alteration comparable to that involved in the propylitic facies of the underlying auriferous series. There is therefore some reason for thinking that propylization of the latter rocks preceded the deposition of the tuffs; but before any definite conclusion, if such is possible, can be drawn from the line of reasoning here indicated a more detailed study of the tuff than that made by the writer will be advisable.

(3.) *Andesites and Tuffs of the "Second Period."*

(*a.*) *Andesites.*

Near Waihi the rocks of the "Second Period" are almost wholly andesitic lavas, which in the main closely resemble one another. They are greyish, bluish, or even nearly black rocks, with numerous phenocrysts of feldspar and pyroxene. Macroscopically they differ from the earlier quartz-andesites or dacites chiefly in being, as a rule, very much less altered. Under the microscope the younger andesites show practically no orthoclase, and, though primary quartz grains are usually present, these occur to a noticeably less extent than in the older volcanic rocks.

The chief type represented is a hypersthene-augite-andesite with a pilotaxitic or semi-pilotaxitic base. The feldspars are usually fresh and well-twinned basic andesine or acid labradorite. The twinning is generally of the ordinary albite type, but other forms are occasionally seen, and good zonary banding is quite common. In very rare instances a crystal of what appears to be orthoclase may be seen in a section.

Quartz, usually present, is in rounded grains of moderate size, and has the same characters as in the auriferous rocks. The occurrence of a very large bleb of white quartz in a sample of andesite collected near the Mataura track by Mr. F. T. Seelye, of the Waihi School of Mines, deserves note. Sections of this, microscopically examined, were found, except in small areas, to be optically homogeneous.

Augite occurs in the usual way, and is in many cases very finely twinned.

A rhombic pyroxene is usually present in abundance. In some slides it predominates over augite, while in others the reverse is the case, but, on the whole, the rhombic and monoclinic pyroxenes are about equal in amount. Generally the rhombic pyroxene is hypersthene, which, while showing well-marked pleochroism, is not of a very ferriferous type, and probably approaches bronzite. In many cases more or less enstatite is present, in some to the total exclusion of hypersthene. The rhombic pyroxenes are decidedly more subject to alteration than the augite. In sections of

specimens from the 500 ft.* levels of the Waihi Extended and Grand Junction Mines they are converted almost wholly into chlorite, and elsewhere are not uncommonly partly chloritized.

In a few slides a little hornblende with resorption border is present. Lozenge-shaped bodies filled with dark dust such as have been observed in the older lavas are not rare and in the absence of further study may be presumed to represent hornblende that has suffered almost complete resorption.

The other primary minerals present in the hypersthene-augite-andesites are magnetite in small grains, apatite in microscopic needles penetrating phenocrysts of feldspar and pyroxene, and possibly one or two of the rarer rock-forming minerals, such as zircon, in tiny grains.

In the Grand Junction and Waihi Extended Mines alteration of the Second Period rocks overlying the auriferous series is in places very marked. Besides the chloritization of the ferro-magnesian minerals, the feldspars may be much decomposed, with the production of calcite, quartz, and "kaolinitic" matter (probably mainly sericite). Though these effects are seemingly of a propylitic nature, they may be partly due to meteoric solutions. In specimens from shafts and boreholes on the western side of the Martha Hill much alteration is also apparent. In this area serpentine is a prominent secondary mineral in the andesites.

Since the decomposed rocks mentioned in the last paragraph are not known to contain any auriferous-quartz veins, it may be supposed that their alteration was not associated with the formation of ore-bodies. The question deserves investigation, however, for the alteration may possibly have taken place during a period when the lodes in the underlying auriferous series were being enriched, or at a time when values in these lodes were being concentrated in ore-shoots.

In the hills towards the coast-line north-east of Waihi are several varieties of andesitic rocks that differ from the ordinary hypersthene-augite-andesite. These, since they occur somewhat outside the area intended to be described in this paper, will not be further mentioned.

(*b.*) *Tuffs.*

On the top of a hill somewhat more than a mile north-west of the Martha Hill is a small outcrop of coarse tuff underlain by a thin clayey layer, below which comes an ordinary andesite. A section made from one of the boulders shows that it is a vesicular hornblende-andesite, with some augite. The vesicles are lined by a yellow undetermined substance. Another boulder proved to be an andesite with beautifully twinned augite and a slightly pleochroic rhombic pyroxene (bronzite). It is quite possible that the tuff under notice belongs to a later period than is here assumed, and ought to be associated with the hornblende-andesites described on page 273.

The andesitic tuffs that appear some miles north-east of Waihi and along the coast-line have not been examined in detail by the writer.

(4.) *Rhyolites.*

As already mentioned, three types of rhyolite occur near Waihi—one spherulitic, the second (wilsonite) with a peculiar flow structure, and the

* In the Grand Junction Mine the exact depth is 494 ft. below the collar of the A or No. 1 shaft.

third a light-coloured fine-grained rock with few phenocrysts. This latter rock contains nests of tridymite, and therefore for the sake of distinction will be designated the "tridymite-rhyolite."

(*a*.) *Spherulitic Rhyolites.*

Macroscopically the spherulitic rhyolites show numerous spherulites, many grains of quartz, and occasional small plates of biotite. A little secondary opal is present in some specimens, and may show good "fire." Under the microscope quartz appears in large grains, with many gas enclosures. Small crystals of plagioclase and biotite may also be present. The greater part of every section, however, is seen to consist of spherulites. The exact nature of the spherulites in Hauraki rhyolites has been discussed by Rutley (5, pp. 451 *et seq.*) and Sollas (11, vol. 1, pp. 120–22). Rutley regards them as being composed of devitrified glass, whilst Sollas, beyond adducing evidence opposed to the devitrification theory, makes no very definite pronouncement.* For the present it may be assumed that the spherulites approach orthoclase in composition, and were formed during the final consolidation of the rhyolites.

In a section of rhyolite from the hills about a mile and a half east of Waihi a quartz-grain is seen to form part of a spherulite boundary. Hence in this case the spherulite is obviously of later formation than the quartz. In the same section a phenomenon which may be termed spherulite within spherulite occurs.

At Waihi Beach a beautifully spherulitic rock is traversed by auriferous-quartz veins. Sections show that the rock is more or less silicified, much secondary quartz mosaic being present. Feldspar (probably orthoclase) appears in imperfect crystals, one of which is imbedded in a spherulite.

A small vein traversing one of the sections from Waihi Beach consists of a fine quartz mosaic cementing and in part replacing fragments of country. It may from this be inferred that the auriferous veins of this locality, like those at Waihi, are largely replacement veins following fracture planes or zones.

The rhyolites referred to above are more fully described by Sollas (11, vol. 2, pp. 35, 112).

(*b*.) *Wilsonite.*

The peculiar rhyolitic rock commonly known as "wilsonite" has been described by Sollas (11, vol. 1, pp. 123, 124; vol. 2, pp. 46, 138). The same rock is mentioned by Park (3, p. 88) and McKay (4, p. 67), and has probably been described by Rutley (5, pp. 460, 461, No. H_{15}).

The freshest obtainable specimens of wilsonite show pinkish or purplish surfaces flecked with numerous black streaks. The fractured rock has a somewhat vitreous lustre. When affected by surface weathering the purplish portion of the rock become nearly white, and the dark portions tend to approach a light-grey colour. Highly weathered rock is of a nearly uniform almost white colour. In places wilsonite tends to pass into a tuff, owing, it is believed, to brecciation of surface portions that solidified before the cessation of flow. Rounded fragments of andesite, usually from ½ in. to 1 in. in diameter, are very common as inclusions in the wilsonite. These are most noticeable in the highly weathered rock, which also is usually the most tufaceous-looking.

* Sollas stated (11, vol. 1, pp. 122, 124) that he intended to deal more fully with the questions of structure, origin, &c., in a final report. This, apparently, was not written.

Porphyritic grains of quartz and feldspar are easily detected in the unweathered wilsonite. Sections examined under the microscope show that the feldspar is mainly oligoclase and oligoclase-andesine. Some of the more basic feldspars may be andesine, or even acid labradorite. A little orthoclase is probably present. Small fragments of ferro-magnesian minerals also appear.

The greater part of the sections consists of a glassy base nearly, but not quite, isotropic. The bulk of the glassy matter shows a streaky flow structure, but there are also small patches of brownish glass not affected by flow. The dark streaks of the hand-specimen are plainly visible, and from the manner in which they pass into the lighter portions the view that the rock is a lava and not a tuff receives emphatic support.

(c.) *Tridymite-rhyolites.*

The tridymite-rhyolites in the neighbourhood of Waihi appear as a number of small flows that at several points may be seen breaking through wilsonite. They are greyish-white rocks of even grain, but somewhat harsh texture. Fluxion structure is usually more or less apparent to the eye, and on close examination small glassy feldspars may be detected. Fragments of andesite, and possibly other rocks, are commonly noticeable. In a flow on the east side of the Martha Hill charcoal has been observed at two points—namely, in the Grand Junction A shaft, at a depth of 110 ft. to 112 ft. from the surface; and in the chamber at No. 3 level adjoining No. 4 shaft, Waihi Mine (depth below shaft-collar, about 195 ft.).

Sections of the tridymite-rhyolites from various localities show that they are composed mainly of a glassy base with a fine corrugated flow structure. The scattered phenocrysts are mostly plagioclase (oligoclase or andesine). Rutley has reported sanidine (5, p. 460). Small broken crystals of green hornblende, augite, and hypersthene (Sollas), probably zenoliths, are occasionally observable. An interesting point is that most of the sections show nests of tridymite, which apparently takes the place of free quartz. Slightly decomposed or altered specimens—for example, the charcoal-bearing rock from the Grand Junction shaft—do not show any tridymite, but secondary quartz may be observed. Magnetite and zircon (Sollas) are present in some sections.

The tridymite-rhyolites near Waihi have been minutely described by Rutley (5, pp. 457–60, Nos. H_9–H_{14}) and Sollas (11, vol. 2, pp. 14–15 and 66–67).

(5.) *Andesitic Rocks of Doubtful Age.*

Under this heading are included some of the younger andesitic rocks that were not sufficiently studied to enable the determination of their relative ages with reference to one another and to the rhyolites to be made. The rocks thus occurring are hornblende-andesites of a variable character.

The most notable occurrence of such rocks is the andesite forming the Black Hill, east of Waihi. In places it shows well-marked though not perfect columnar structure. The rock is not very uniform in appearance, but in the main is a dark-grey hornblende-andesite, sections of which, besides abundant hornblende, show a little augite, and in places biotite. The feldspar phenocrysts are probably oligoclase-andesine. A little magnetite and apatite in fine needles are present. A nearly isotropic mineral of very low refractive index was not determined. The base contains numerous feldspar microlites, and with a $\frac{1}{6}$ in. objective exhibits a kind of feathery appearance under crossed nicols.

Sollas (11. vol. 2, pp. 13, 14) describes a sample of rock from the Black Hill as a light-grey hyalopilitic andesite, with hornblende and biotite. He also mentions the possible presence of quartz and tridymite.

The Black Hill andesite contains in places small fine-grained segregations. One of these on microscopic examination exhibits numerous small feldspar laths of rather basic type (labradorite), together with small phenocrysts of augite, chlorite, and plentiful magnetite imbedded in a glassy base. The structure is reminiscent of an ordinary basalt. The transition border consists of large feldspars near andesine, with some hornblende, enstatite or hypersthene (near bronzite), biotite, and quartz (very rare) imbedded in an obscure apparently more or less glassy base.

One section of a rock from a spot on the east side of the Ohinemuri River about a mile and a half north-east of Waihi shows a hornblende-andesite with some biotite, augite, and hypersthene (rare). A second section contains more hypersthene, but less augite and biotite. It thus approaches very nearly the Black Hill rock described by Sollas.

About two miles and a half west of Waihi, along the course of the water-race to the Victoria Battery (Waikino), there occurs a hornblende-andesite with some augite and enstatite (or bronzite). The two sections made differ considerably in the relative proportions of rhombic pyroxene, so that a want of homogeneity in the rock-mass is again apparent.

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ART. XXXII.—*A Note on the Structure of the Southern Alps.*

By P. G. MORGAN, M.A.

[*Read before the Wellington Philosophical Society, 5th October, 1910.*]

IN Hochstetter's "New Zealand" (English translation), on page 487, two geological sections from east to west across the South Island will be found. One of these, after Hector, is drawn through Otago; the other, drawn through Canterbury and Westland, was supplied by Von Haast, and illustrates with a considerable degree of correctness the structure of the Southern Alps. In discussing the latter feature, Hochstetter says, "A simple glance at the above sections shows, furthermore, that only the eastern half of a complete mountain-chain has been preserved, while the western half is buried in the depth of the main" (1,* p. 489). As a matter of fact, however, the sections do not prove the truth of Hochstetter's statement, which rests rather upon a hypothetical basis. One object of this note is to show that, on the contrary, the Southern Alps are not, as Hochstetter supposed, the remnant of a vastly larger range that once extended far to the westward of their present limits, but retain the same, or almost the same, dimensions as at any past period of their history.

Hochstetter's opinion, however, has been adopted by most New Zealand geologists. In 1879 Von Haast writes, "This remarkable chain, of which the geological structure is generally uniform throughout, is only the eastern wing of a huge anticlinal arrangement, of which the western portion has either been destroyed or submerged below the Pacific Ocean. It has thus the same one-sided arrangement, so conspicuous in almost every alpine chain of which the geological structure is known. The axis of this anticline consists of granite and other plutonic rocks" (2, p. 242).

At a later date Hutton, repeating part of Von Haast's statement almost word for word, says that "the mountain-range is only the eastern half of a huge geanticlinal arrangement of contorted rocks, the western half having

* This and other numbers similarly enclosed in brackets refer to list of literature at end.

been washed away by the heavy rains which fall upon that side, and which must have fallen for a very long time to have produced so great an effect" (5, p. 161).

In recent years Marshall (7, p. 98; but see also 11, p. 445), Park (12, p. 16), and others appear to have accepted Hochstetter's explanation of the structure of the Southern Alps without question. In 1908, however, the writer pointed out that a series of ancient rocks designated by him the Greenland series* occurs along the western margin of the Southern Alps. These rocks, if Hochstetter's hypothesis were correct, should show the same folding as the rocks of the Arahura series, which form almost the whole of the Southern Alps; but, instead of that being the case, it is found that they are folded almost at right angles to the trend of the Alps (10, pp. 31, 36, 97). This fact is completely opposed to the idea that the present alpine chain is "only the eastern half of a huge geanticlinal" of which the western wing has disappeared.

The great difference in lithological character between the schists east of the granitic mountains that have been supposed to represent the core of the alpine anticlinal and the much less metamorphic argillites and greywackes of the Greenland series in a corresponding position on the western side of the granitic mountains is in itself strong evidence against what may be called the Hochstetterian view.

Von Haast was undoubtedly to some extent aware of the structure of the Greenland rocks, and it was probably in order to avoid the difficulty of reconciling this with the structure of the Arahura series, as well as to obviate the difficulty caused by the difference in lithological character, that he supposed his Westland formation to be (in part at least) younger than the alpine folding (2, p. 244). There appears, however, to be no field evidence of any kind in favour of this view.

What, then, is the general structure of the Southern Alps? As has been elsewhere pointed out by the writer (10, p. 43), an exposition of the principles underlying the answer to this question may be found in Eduard Suess's great work, "The Face of the Earth," where it is maintained that folded mountain-chains of the alpine type are due to overthrusts along lines where more yielding strata are pushed against buttresses of immovable rocks. In the case of the Southern Alps, Suess's main criteria are satisfied. There is a gentle rise from one side—the east—and a steep descent on the other. The strata on the western side are overturned schists. Along the western margin are great faults, believed to be of the overthrust type (10, pp. 43, 71). These faults are associated with a line of granitic mountains,† which correspond to Suess's cicatrices that mark a wound in the earth's crust. To the west of these, beyond the main overthrust, comes a buttress of Greenland sedimentaries, folded in most places almost at right angles to the alpine strike.

Some imperfections in the field evidence that occur to the writer may here be mentioned. North of the Waitaha River granite is well developed along the base of the Alps, but for a hundred miles or more southward no granite except a small outcrop in Mount Bonar (10, p. 132) has been observed. Again, the Greenland buttress is apparently by no means continuous along the western base of the Alps. It is, however, well developed from Bell

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* Equivalent to part of Von Haast's Westland series (2, p. 256), and to Bell and Fraser's Kanieri series (8, p. 19).

† In places gneiss partly covers the granite.

Hill northward,* is seen at Lake Kanieri, and forms a considerable area east and south-east of Ross. Greenland rocks appear near Lake Mapourika, and probably have some development farther south. The breaks in the buttress are attributed by the writer to down-faulting, which also is thought since Miocene times to have caused the disappearance of an ancient land-mass to the seaward of the present coast-line (3, pp. 26–28).

Suess distinguishes two types of overthrust mountain-ranges — the Atlantic, with its outer or overthrust face directed away from the nearest ocean; and the Pacific type, with its outer face directed towards the nearest ocean. As judged by these definitions, the Southern Alps, though of the Pacific type with respect to the Tasman Sea, are of the Atlantic type with respect to the South Pacific Ocean. This has already been indicated by Marshall (11, p. 445).

If, as has been assumed throughout this note, the folding of the Greenland rocks from north-west to south-east is older than the folding of the Arahura or alpine rocks from north-east to south-west, then in the alpine region the former folding has been superimposed on the latter. Confirmation of this view is afforded by field evidence. According to observations made by Mr. E. Dobson many years ago, the average strike of the strata forming the Southern Alps is N. 22° E., whilst the trend of the range itself is N. 55° E. (1, p. 485). More recently the New Zealand Geological Survey has noted considerable irregularities in the strikes of the alpine rocks in North Westland (8, p. 42; 10, p. 78). These irregularities increase from the intensely folded western schists in which the supposed older folding has been almost obliterated towards the main divide, and are very marked on the eastern, or Canterbury, side. Practically all the irregular strikes, except one or two that are nearly east-and-west, fall in the N.E.–N.W. quadrant, and are therefore such as might be expected to result from a folding-force acting from the south-east on strata with an original north-west to south-east strike.

Similar irregularities in strike are very apparent in north-west Nelson in rocks of the Aorere series (9, p. 34). It is here suggested that a similar cause to that indicated above may be assigned for the strike-irregularities in this area and in other parts of New Zealand—for example, the Whangaroa Subdivision (Bull. No. 8, N.Z. Geol. Survey, p. 42).

This note refers mainly to that part of the Southern Alps with which the writer is acquainted—namely, from the Otira district for about a hundred miles southward. Thus the Southern Alps as they pass north-eastward through Nelson to the shores of Cook Strait, the interesting central knot of Mount Cook, and the comparatively unknown southern portion of the range are not discussed. Before an authoritative opinion concerning the structure of the whole range can be given, a detailed geological survey of practically its entire length, and more especially of the district south of Mount Aspiring, where the Alps begin to lose their identity in the mountain complex of western Otago, must be undertaken.

In conclusion, it may be said that a full and correct statement of the structure and history of the Southern Alps will be of great importance in aiding the solution of several problems in New Zealand geology, and possibly of still greater value in connection with the elucidation of the wonderful but baffling geophysical problems presented by the Pacific Ocean.

* This district, however, is outside the scope of the present note. See last paragraph but one.

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The literature listed at the end of 11 may also be consulted with advantage.

Art. XXXIII.—*Rotomahana and District revisited Twenty-three Years after the Eruption.*

By H. Hill, B.A., F.G.S.

[*Read before the Hawke's Bay Philosophical Institute, 24th June, 1910.*]

The Tarawera eruption took place on the 10th June, 1886. In the months of February and March following I visited the volcanic area extending from Ruapehu to Mount Tarawera. My purpose was to study volcanic phenomena as presented by this almost unique extent of country, known generally as the Taupo volcanic zone. The distance in a straight line is a little over a hundred miles. Within this extent of country all aspects of volcanic phenomena occur, from the active volcano, as Ngauruhoe and Tongariro, to the slowly dying ngawha and puia as seen at places like Tokaanu, south of Lake Taupo, and Rotokawa, a few miles to the north of it. Twenty-three years have gone by since that visit took place, and in company with A. J. Morton, Inspector of Schools, Westland, I have purposely made another visit to the northern portion of the district, or more particularly that portion which was directly affected by the eruption in 1886. Twenty-three years is a fair measure of time in the life of an

individual, and it provides a kind of standard in estimating the physical changes of a district when they are unaffected by artificial agencies.

The past, as read in the rocks about us, goes a long way back, and our ideas of time are so limited that none of us can measure a geological period without some standard of time in relation to moving events as they affect the human race. We know literally nothing as to the incoming of special formations of rocks, or the time that it took in their making; nor do we know whether fifty or a thousand centuries have elapsed since the present forms of organic life came into being. In nature's ever-active workshop changes are going on, and how small is the period which our modern fauna and flora represent of the evolutionary process that has ever been in operation, which embraces the whole gamut of past life down and back to the time when life first became possible on a cooling earth. It was some such thoughts as these that led me to renew my acquaintance with a district that had formed the subject of scientific dissertations, that had been the scene of stupendous changes in mountain, lake, and valley, and which in a brief six hours had produced devastation over a vast district estimated in thousands of square miles, and but for the isolation of the area would have resulted in the loss of many lives. Every living plant and animal within some miles of the centre of volcanic disturbance was destroyed, and there was also loss of human lives.

It is not necessary for me to refer at length to the extent of the destruction caused by the Tarawera eruption. Details were published throughout the Dominion and are still available to inquirers, and scientific accounts have been issued under the authority of the Government. Among these may be mentioned the separate accounts by the late Sir James Hector, Director of the Geological Survey; by the late Captain Hutton, F.G.S., F.R.S.; by Professor Thomas, M.A., F.G.S., of University College, Auckland; and last but not least by Mr. Percy Smith, F.R.G.S., late Surveyor-General. The accounts given by these scientists provide valuable literature dealing with certain aspects of vulcanism as obtained immediately following the outbursts at Tarawera.

As already remarked, the scene of the eruption was visited by me in February and March, 1887. My guide was the late Mr. J. C. Blythe, who had passed through the ordeal of the eruption at Wairoa Settlement, on the west side of Lake Tarawera, when the place was utterly destroyed. Mr. Blythe was Government officer in charge of the road-construction, and he knew intimately the whole country extending from Galatea to Taupo and from Taupo to Rotorua. His knowledge of the district was of much value to the authorities immediately following the eruption; but, although he lived to help many, and to tell others subsequently of his never-to-be-forgotten experiences on the eventful morning of the 10th June, his nerves were so shattered that he became a wreck of his former self, and, although as an old friend I tried to cheer him at my home in Napier, it was only of temporary benefit, for on his return to Rotorua district he lived for only a comparatively short time. Mr. Blythe was my guide and companion from Rotorua over the whole of the country that had been immediately affected by the eruption. We visited the rift in the Tarawera Mountain, the site of Wairoa, Rotomahana crater-basin, the earthquake flats towards Pareheru and the Tikitapu; the crater-valley forming a continuation of the rift, and which subsequently became so celebrated or notorious by the break-out at Waimangu; the mountains known as Kakaramea and Maungaongaonga, at the head of the Waiotapu Valley; and finally made our way through

the latter valley, and christened the place known as the Primrose Terrace. At that time the Waiotapu Valley had hardly been visited by Europeans, and but for our guide the visit would have been a dangerous if not a foolhardy undertaking.

One well remembers the scene of desolation that appeared after getting over the hills from Whakarewarewa, near Rotorua. Looking towards the Tikitapu Bush and the lake and mountain known as Tarawera, the country presented a dull-grey appearance, and not a truce of grass or fern or bush was to be seen. A valley on the road to Tikitapu had been rent in twain by an earthquake, which had produced a gulch from 30 ft. to 40 ft. in width and 50 ft. or more in depth. This extended for a long distance, and divided into three cracks or prongs to the eastward, where the rift shallowed. It seemed as if a sudden uplift had taken place, and that a wedge-shaped piece had been suddenly broken from the valley-level and had fallen and wedged itself as the upward strain was lessened and the surface pressures gave their usual stress upon the underlying rocks. The sides of the crack were vertical, as if sheared with an instrument, although nothing but pumice appeared in the sides throughout the entire length of the depression. Further in the direction of Te Wairoa Settlement the site of the Tikitapu Bush was reached, but everything had been destroyed by the falling *débris* and the battering of the trees by the mud that was flung from Rotomahana. The Tikitapu Lake and its adjoining one, Rotokakahi, which at present are known as the Blue Lake and the Green Lake respectively, presented a desolate appearance, the sides being mud-clad, and large furrows showed themselves from the hillsides, where the rains had carried material into the lakes during wet weather. The small stream from the Green Lake had been dammed back by the mud, and the entire country presented not a trace of either animal or vegetable life.

The Te Wairoa Settlement had been the residence of a number of Natives. There was a church, a Native school, and an hotel, the latter being specially built for the convenience of tourists to Rotomahana. Everything had been destroyed; not a house was left intact, and the majority had been overwhelmed. A Native whare belonging to Guide Sophia had stood, being protected by its position, and this place formed a "whare of refuge" for a number of persons who sought its friendly protection. The church and school were destroyed, and Mr. Haszard, the schoolmaster, with a number of others, lost his life. From the roof of the church one could see where the services had been held, and "Church Services" were to be seen here and there besprinkled with mud, but all, or nearly all, those who had formerly worshipped had lost their lives. The picture remains in my memory, and it is set down here twenty-three years afterwards to show the impression made upon me, for I have not previously written on the subject.

We continued our journey towards Rotomahana and the great rift, and from the hill named Te Hape-o-toroa, overlooking what had once been the hot lake Rotomahana, containing an area of about 200 acres, and abounding with terraces, puias, ngawhas, and geysers, there appeared an immense yawning abyss, from which steam arose as from hundreds of throats that at times sent out dismal sounds and hissings as awesome as from Dante's inferno. The sight cannot be described, and one could only wonder as to the forces that in the course of a few hours produced such an enormous crater in place of a hot lake and its inimitable terraces. Great steam-clouds rose from the abyss, and from the rift in the mountain, and

from several crateral lakes near by. Sometimes the southern slope of the Tarawera chasm or the mountain could be seen. Here the volcanic forces had rent asunder a whole mountain-side before reaching Rotomahana, where the volcanic phenomena were quite different from those on the mountains. Stones and cinders, ashes and sand, with an abundance of the finest powdery steel-grey dust, were hurled from the mountains, but mud alone, of a bluish-grey colour, appears to have been sent from the Rotomahana Crater. We followed the rift towards Okaro Lake, and saw the various crater-shafts that had been made in various places. Some of them had thrown out enormous stones, tons in weight. These had fallen into the mud-covered area, and had made depressions that presented a curious saucer-like appearance over the country. Some of the craters were mere circular shafts of great depth, but we were unable to form an estimate of the depth, as the stones rolled into them sent back no thud or sound of any kind. To me the rift had the appearance of a great upheaval of country where a line of hills had been rent or torn asunder and thrown apart, leaving the rift-valley between them.

The destructive effects of the eruption were not felt to the southward beyond the ridge that separates the drainage of the Rotomahana area from the Waiotapu Valley, for, although careful observation was made, the only trace of activity having occurred in the valley was the discovery of small globules of black sulphur near to the Primrose Terrace, and within a short distance of the great mud volcano near a terrace formation.

Nature heals very rapidly the wounds she makes. Rearrangement and renewal are always in progress, and no sooner has one aspect of the earth's crust played an important part than new energies begin to manifest themselves, so that the old is quickly replaced by the new.

Before, however, noting the changes that have taken place as noted by me, it may be of some value to future inquirers to set down here what was known by Europeans of Rotomahana and Tarawera up to the time of the eruption. In no record that has come under my notice is the Waiotapu Valley mentioned, and the first European to visit Rotomahana was the Rev. Mr. Chapman, a missionary. In the *Missionary Record* of June, 1838, it is reported that Mr. Thomas Chapman started from Paihia (Bay of Islands) for Rotorua on the 2nd February, 1835, with a Mr. Pilley, and that they reached the place on the 19th March. In August of the following year the missionary station at Rotorua was burnt, and Mr. Chapman went to Taupo, where, in May, 1841, he met Dieffenbach, the scientist sent out by the New Zealand Land Company. Dieffenbach had been to Tokaanu, and was travelling northward when he appears to have met Mr. Chapman, from whom he obtained information about Rotomahana. On the 1st June Dieffenbach reached Rotomahana, and he writes, "Towards evening [1st June] we reached the hills which surround on all sides Rotumahana. When we arrived on the crest of the hills the view which opened was one of the grandest I had ever beheld. Let the reader imagine a deep lake of blue colour surrounded by verdant hills, in the lake several islets, some showing the bare rock, others covered with shrubs, while on all of them steam issued from a hundred openings between the green foliage without impairing their freshness; on the opposite side a flight of broad steps of the colour of white marble with a rosy tint, and a cascade of boiling water falling over them into the lake. Some Natives came over in a canoe to fetch us over the lake to their settlement. Mr. Chapman was probably the first European they had ever seen, as this lake has not been

visited by any other that I am aware of. The Rotu-mahana is not more than a mile in circumference. We crossed from it in a canoe into the lake Tarawera. The stream connecting them is tepid, and of a temperature of 85°. It is appropriately called Kaiwaka (canoe-spoiler), as the canoe often touches the rocks of which the bottom is formed."

In the "Tasmanian Journal of Science," vol. 1, page 268, there is given an account of a journey by the late Rev. W. Colenso, F.R.S., taken in the North Island of New Zealand in 1841–42. Mr. Colenso reached late one night Lake Rangiwaka-aita, now known as Rerewhakiatu, which is situated about two miles to the east of Lake Rotomahana. He describes the former lake, and states that the country was overspread with many blocks of compact lava, many being vitrified on the surface. The ground rose gently from the lake on every side, which appeared to occupy a deep hollow, and "I could but venture to suppose that this might perhaps have been the crater of a volcano which in some bygone age inundated the whole country with showers of pumice and ashes. At an early hour the next morning we rose, feverish, stiff, and sore, to recommence our march. We soon came within sight of the place where the hot springs were situated [Rotomahana ?], from which the steam and sulphurous vapours ascended in dense white clouds. The air this morning was cool and bracing, and after travelling about an hour and a half we arrived at Tarawera Lake [Te Ariki ?]. At this place were several small hot springs, which flowed out of the earth near the edge of the lake; the water of some was hotter than one could bear. . . . The Natives of the village informed me that at a spring on a hill a little distance away the water was quite hot enough for the purpose of cooking, for which they often used it. Sulphur, too, abounded there, and was often 'thrown up' out of the earth, from which the steam and smoke ever ascended [the White Terrace ?]." This "steam and smoke" was, of course, from Rotomahana geysers and puia, and although Mr. Colenso started to visit the place while breakfast was getting ready, he gave up the quest, "his hunger," as he said, "conquering curiosity"; and thus he missed, although less than three-quarters of a mile away, seeing, as the third European visiting the district, the inimitable terraces. It is strange that a missionary traveller like Mr. Colenso, who was so very observant, should have passed from the east to the north end of Rotomahana by way of the south and west and yet did not see the lake.

Hochstetter was the next traveller of note to visit Rotomahana. He spent three days in April, 1859, visiting every place of interest within the precincts of the lake, and made observations of great scientific value. The map of Rotomahana Lake by Hochstetter and Petermann, published in 1863 at Gotha by Justus Perthes, is the only map, as far as I can discover, that appeared in an official dress or under authority previous to the eruption. Of Rotomahana and the Terraces Hochstetter thus writes: "The Rotomahana is one of the smallest lakes of the lake district, not even quite a mile long from south to north, and only a quarter of a mile wide. According to my measurement it is 1,080 ft. above the level of the sea. Its form is very irregular on the south side, where the shore is formed of swamps. Three small creeks are meandering and discharging themselves into the lake—the Haumi, from the south-west; the Hangapoua, from south-east; and the middle creek without a name. Numerous observations lead to the conclusion that constant changes are going on at Rotomahana—that some springs go dry, others rise, and especially the earthquakes which are felt here from time to time seem to exercise such a changing

influence. The main interest is attached to the east shore. There are the principal springs to which the lake owes its fame. First of all is Te Tarata, at the north-east end of the lake, with its terraced marble steps projecting into the lake, the most marvellous of Rotomahana's marvels." The two islands Pukura and Puai that were situated in the lake, equally with geyser, puia, and ngawha, were carefully described by Hochstetter, whose observations and painstaking work are a model to students of science. Of Mount Tarawera he remarks, "The chief ornament of the adjoining landscape is the Tarawera Mountain, with its crown of rocks divided into three parts by deep ravines: it rises on the north-east side of the lake to a height of at least 2,000 ft. above the level of the lake. It is an imposing table mountain, consisting of obsidian and other rhyolite rocks, and it is not to be wondered at that its dark ravines and vertical sides have given rise to many an odd story in vogue among the Maoris. Among others, a huge monster, 24 ft. long, resembling a crocodile, is said to haunt the clefts of the rock, devouring every one who dares to scale the mountain."

The next writer that describes Rotomahana and Mount Tarawera is Domett, in his inimitable poem, "Ranolf and Amohia." Mr. Domett was at one time Resident Magistrate and Commissioner of Crown Lands in Napier, and he had a fine grasp of Native legends, and he has made good use of them in the above poem. Domett retired from the Government service in the year 1871, and the following year "Ranolf and Amohia: a South Sea Day-dream" was published. Ranolf is a young Englishman and Amohia a Native young woman of high caste. They love one another, and, leaving the girl's home, they wander over the country and at last reach the south end of Lake Rotomahana. They see a canoe which has evidently not been in use for some time, so they untie it, and finding a paddle they move towards the Pink Terrace:—

As at the closing of a sultry day,
In search of some good camping-ground
They paddle up Mahana's Lake,

* * * *

A mighty cataract—so it seemed—
Over a hundred steps of marble streamed
And gushed, or fell in dripping overflow;
Flat steps, in flights half circled—row o'er row;
Irregularly mingling side by side:
They and the torrent curtain wide
All rosy-hued, it seemed with sunset's glow.

They continue their journey northward across the lake and they come to the White Terrace, which is thus described:—

They paddle past, for on the right
Another cataract comes in sight:
Another broader, grander flight
Of steps, all stainless, snowy-bright!
They land; their curious way they track
Near thickets made by contrast black;
And then that wonder seems to be
A cataract carved in Parian stone
Or any purer substance known—
Agate or milk chalcedony!

* * * *

Each step becomes a terrace broad;
Each terrace a wide basin brimmed
With water, brilliant, yet in hue
The tenderest delicate hare-bell blue
Deepening to violet.

This description of lake and mountain could only have been written by one familiar with both. Neither Dieffenbach nor Hochstetter has described the lake, the geyser, puia, and ngawha in greater detail than Domett has done in his inimitable 17th canto, into which the actions of two young lovers are wound with rare poetic power.

Two English writers of eminence visited Rotomahana before the great catastrophe took place, but neither Trollope nor Froude possessed any special scientific knowledge; and although their descriptions, particularly that by Froude in his "Oceana," form delightful word-pictures of the inimitable White and Pink Terraces they contain nothing beyond what has already been stated concerning Rotomahana and its marvellous surroundings.

Since the eruption in 1886 very little has been written concerning this interesting district. In March, 1893, Mr. Percy Smith, who was at the time Surveyor-General, visited the country immediately round the site of the Tarawera eruption, and noted some of the changes that had taken place. Referring to Rotomahana, Mr. Smith says, "The two lakes existing soon after the eruption [Rotomahana and Rotomakariri] have since become merged into one, and the bounds very greatly extended—so much so that instead of a surface of 25 acres for the two lakes in August, 1886, they now cover, roughly, 5,600 acres, and at the same time the waters have risen from a level of 565 ft. to 985 ft. The lake as at present existing is bounded on all sides by steep hills, which formed the walls of the great crater in June, 1886." Since this was written Lake Rotomahana has continued to enlarge, and at present it extends from north to south more than five miles, and in its widest part reaches nearly two miles and a half, and contains an area of about 7,500 acres.

Hochstetter pointed out that the lake was fed by three streams. The only stream that is seen to flow into it at present is the Haumi, which comes from the chasm towards the south; but another stream flows into the lake abreast of the small island known as Patiti. This stream comes from Lake Rerewhakaihu, and for a portion of its course runs underground. The rapid increase of water in the lake, and the merging of Rotomakariri and Rotomahana so soon comparatively after the eruption, suggests that the lake must be supplied largely from some underground source. Possibly the water that falls upon Tarawera and Ruawahia drains into Rotomahana by way of the chasm, so that it is likely the lake will continue to increase, and subsequently be merged with the Rerewhakaihu Lake, which is estimated to be between 30 ft. and 40 ft. above that of Rotomahana. But, as Rotomahana has only to rise a little more than 30 ft. before being able to burst through and form a channel into Lake Tarawera, an interesting problem presents itself which time alone can solve. Should the time arrive when Rotomahana breaks through into Tarawera, a dangerous rush of waters will take place that might result in serious damage to the low-lying country in the vicinity of Te Teko. But Rotomahana as a lake has plenty of room for expansion to the southward, and this it is now doing along the line where the activity at present is most powerful. The thousand steam-vents that were to be seen in 1887 have all been covered by water, but they are no doubt as active as ever. The pressure of the overlying water keeps them from exploding, but the steam-vents along the south-west sides of the lake are extremely active, and present features that imply rapid changes underneath. Along the fissure towards the south, near the place where tourists enter and leave the launch when coming from or going to

Okaro Lake, the steam-vents are powerful and excessively active; and along the entire chasm there are many signs of unusual activity, steam being forced through the rock at very high pressure.

The water of the lake is of a greyish-green colour, and contains a fair amount of mud in suspension. The lake is bounded by high walls of pale-blue mud, which are easily washed away in time of heavy rain. This may account for the colour of the lake-waters; but the Haumi Stream also carries down plenty of mud—in fact, during heavy and stormy weather the stream must carry down an immense quantity of material from the soft pasty mass of the area which the stream drains.

The country, wherever it was covered with material from Rotomahana, presents a curious appearance. The blue clay is mixed with scoria that was thrown from the mountains, and they appear to have fallen together in many places. The surface becomes hard and gritty, and yet in time of rain deep ruts or gutters are quickly formed, and there appears surface-characteristics that are not seen under ordinary physical conditions. Every rut represents a drainage-basin from two adjacent slopes that may not be more than 2 ft. or 3 ft. wide, but of fair length; and the drainage from this miniature watershed and basin forms in time ruts of extreme depth, resembling a crevasse in the ice. These provide pitfalls to the unwary, and it is impossible for a horse to pass across country where these ridge-like places abound. As time goes on, these miniature-basin areas will merge, and the basins will grow fewer and fewer as erosion breaks down the ridges. In some places where grass was sown there are few ruts, and comparatively little damage to the new surface has taken place. But the lesson to be learnt is that resulting from the action of the weather upon a surface that has to be supplied with a covering of vegetation in nature's own way, and the growth of an ordinary river-basin by the merging of hundreds and even thousands of tiny miniature basins where the old basins have been obliterated presents even to-day an object-lesson of the utmost interest in the physical evolution of surface-features in a country.

At the time of the eruption the mountains presented the appearance of having been torn and wrenched by some great titanic force. The south end of Mount Tarawera, known as "The Chasm," ran towards the lake from nearly the front crest of the mountain. This chasm is now quiescent, and but for the colour of the material and traces of scoria it would be difficult to suppose that the rift had been made within the past quarter of a century. Immediately above the chasm there is a fringe of black lava that has evidently flowed into its present position. It passes over the crest, and is lost in a dip of the mountain which has been filled with scoria and other material thrown from the craters further along the mountain. The appearances suggest that, before the chasm burst, an opening in the mountain further to the north had been made from which lava—a heavy dark lava—had commenced to flow. The late Mr. Blythe stated that he saw a stream as of moving lava, and was supported by others. Between this place and the first of the craters is a dip from which one rises to the flat, where the first crater is seen. This flat area is ridged, and shows a series of earthquake-cracks running north-east and south-west. The depressions have formed places of safety for lowly forms of vegetation, and several varieties of ferns were collected among other specimens of plants. The two craters on Tarawera are separated from each other by a kind of rock partition. The walls of the craters on the west and north more particularly show varying coloured bands of scoria and cinders, which have a

thickness in some places little short of 80 ft. As this banded scoria is vertical in the side of the crater, it would seem as if the scoria had been deposited from another crater before the explosion occurred that produced the adjacent craters. The largest and deepest craters are those on Ruawahia and on Tarawera, whilst the scoria is deeper than is shown on the most southern of the Tarawera craters.

The gut or saddle that separates Wahanga from Ruawahia has a crater differing from all the rest in shape and formation. The sides are formed into ledges or terraces, and the material on the platforms resembles white sand (feldspar crystals ?). The two craters on Wahanga are at the eastern side, and not on the top, as in the other mountains, and the scarp can be seen by passing ships from the Bay of Plenty.

The scoria in each crater is covered at the present time with a curious lichen (*Collema ?*). In the damper places it gives the scoria a peculiar appearance, as if coloured by aerial action, and it leads an observer to suppose that the craters were formed at a remote period rather than at a recent date.

Along the west side of the mountains overlooking Lake Tarawera a bold embattled top front with vertical sides is formed, below which the material is loose, and is made up, apparently, of the remains of the explosions from the craters on the top. The rock varieties are few, and there are no traces of mud such as is found over the country that was affected by the explosion in the Rotomahana Lake.

A great and marked change has taken place in the general surface-features of the country. The Tikitapu Bush that was destroyed has in a large measure reappeared. Fern has covered the valleys in many places, and where grass-seed was sown shortly after the eruption it has grown and provides an abundance of food for sheep and cattle. The place known as Te Wairoa, which was destroyed, is again being reoccupied, whilst most of the area in the vicinity is covered over with a variety of plant-life, some native and some foreign. An Australian acacia (*A. decurrens*) has become the principal tree, and its growth is so rapid that the residents of the place use it for firewood. The plants are of a lowly type, but they show how the surface is quickly reclothed if the soil is suitable.

Thus a township was overwhelmed with material from a mountain and a lake ten miles away, and to-day, after the brief space of twenty-four years, hardly a trace remains to show that such actually took place. The country is again covered with vegetation, the bare and desolate places have been reoccupied, and organic life has reasserted itself over hill and mountain and valley. The lakes Tikitapu, Rotokakahi, and Tarawera have returned to their former conditions, being either of a deep blue or green colour, so that sedimentation of the material that fell into them at the time of the eruption has been long since completed.

The ridge of land that at present separates Lake Tarawera from Rotomahana is less than a mile across, and, though bare in parts, grasses of various kinds grow well, clovers flourish, and a fair variety of native plants abound. A similar remark applies to the mountains. Two varieties of *Lomaria* ferns, two species of *Epilobium*, three species of *Gaultheria*, two *Veronicas*, a *Dracophyllum*, and four varieties of grasses were found, in addition to *Coriaria ruscifolia* (tutu), which is common towards the lower part of the mountain overlooking the lake. And this was at the end of the summer season. No doubt in spring the variety is much greater; but the specimens collected by me show that the mountain-sides are being

reclothed with vegetation adapted to the physical conditions at present existing.

An interesting question arises as to what the future of the volcanic area is likely to be with Rotomahana as a centre. When Mr. Percy Smith wrote in 1893 the lake was 985 ft. above sea-level, and had risen 420 ft. in less than eight years. Sixteen years have since elapsed, and Rotomahana has risen an additional 65 ft., has largely extended its area, and is now within 30 ft. from the lowest point in the direction of Lake Tarawera; and in the meantime much of the devastation caused by the eruption has been obliterated—so much so that a stranger unacquainted with the facts of the eruption would fail to realize that within so short a period as twenty-four years an entire district, occupying thousands of square miles, was affected by the material from a volcanic explosion, whilst tens of thousands of acres of land were covered with mud and volcanic *débris* and all vegetable and animal life destroyed.

And yet this process of destruction and renewal is ever active. The Tarawera eruption is not the only one that has taken place in the history of vulcanism in this Island. Similar eruptions have taken place in the Waiotapu Valley, at Rotokawa, and Wairakei, in the Waikato from Tapuharuharu to Orakeikorako, and in Taupo itself. The Taupo Plateau has been covered and built up of products from explosions such as those of Tarawera Mountain and Rotomahana Lake. Nor should the student of vulcanism separate the Tarawera country from the other portions of the volcanic district, the old as well as the new; but this aspect of the question must be left for discussion until the second portion of my paper on the Taupo Plateau is considered. There my desire is to throw out a suggestion as to the reclothing of the earth's surface with organic life following a period of great volcanic activity. It has always been a puzzle—nay, a mystery—how new plants and animals appear at the outgoing of one formation and the incoming of another. All traces of the previous forms of life are not destroyed, but new species come in and old ones die out. Does an eruption like that of Tarawera and Rotomahana afford any clue to the answer? It seems to suggest a possibility.

In times gone by explosions have been on a much grander scale than are now experienced, and much larger areas of country were affected. Organic life must have suffered, and at times have been almost destroyed; and adaptation to the new environment was enforced on the flora and fauna that were not swept away. Surely there is some probability that the life within special areas would be largely affected in this way, and when the forms of life extended from other districts and came within the limits of the conditions existing following an eruption a merging must take place so as to conform to the new conditions. Could animal and vegetable life undergo marked modification by such means? It may be possible, but it is difficult to put the matter to a test.

A separate inquiry into the botany of the Taupo Plateau may provide some suggestive matter, as showing specialization or variation from specific types; and now that attention has been called to the subject some botanist of leisure may think an inquiry on this point may not be unworthy of his observation.

Art. XXXIV.—*Napier to Runanga and the Taupo Plateau.*

By H. Hill, B.A., F.G.S.

[*Read before the Hawke's Bay Philosophical Institute, 24th June, 1910.*]

Although a good deal has been written about the volcanoes of New Zealand from the time when Hochstetter paid his celebrated visit in 1859, very little is yet known of the Taupo Plateau and the rocks that either bound it on the east or are found upon it here and there in exposed areas. Hochstetter and the late Sir James Hector, F.R.S., issued maps of the so-called volcanic district, but they were theoretical rather than actual, as the larger portions of the district were not visited by either of these careful observers.

Few other places in the world present better opportunities for observation of volcanic phenomena of the present-day type than does the area embraced mainly within the Taupo-Waikato basin; but this constitutes only a small portion of the area that is geologically included within the true volcanic zone.

The paper by Dr. Marshall (Trans. N.Z. Inst., vol. 40, p. 79) on "The Geology of Centre and North of North Island," and the descriptive account of the volcanic cones south of Lake Taupo by Mr. Speight, B.Sc., F.G.S., in the admirable botanical-survey report of the Tongariro National Park by Dr. Cockayne, have given increased importance to the volcanic district, but much remains to be done before complete information can be made available covering the geological history of this interesting district.

The key to the physical evolution of the North Island is to be found in the true interpretation and history of the volcanic area.

In company with the Director of the Dominion Museum, Christmastide was spent in studying that portion of the Taupo Plateau extending from Runanga to the Rangitaiki River, thence to Loch Inver Station, on the northern slopes of the Kaimanawa Range, finishing at Taupo. This work I had another opportunity of reviewing at Eastertide, being anxious to complete a geological section along the coach-road from Napier to Taupo. This section (fig. 1) shows the beds to be met with between the sea-beach at Petane, where the coach-road strikes inland, and Taupo; but the section is continued to Karangahape Head, on the west side of the lake, as the intention is to give in another paper a similar section from Whakatane to Ruapehu, through Lake Taupo. Fig. 2 gives a map of Lake Taupo to scale, with the most important geological features.

A reference to fig. 1 shows Pliocene beds of Napier upper limestone near the Motor Company's stables at Petane. These in places are overtopped with shingle conglomerate representing the Kidnapper shingle conglomerates. The middle beds of the Pliocene series appear up the hill before reaching an elbow in the road, where again the shingle conglomerates top the limestones. No change takes place in the general characters of the Middle Pliocene series through the whole length of the Esk Valley; but the overlying shingles, sometimes mixed with sand, become thicker and thicker, and on the left bank of the river they are seen dipping to the south-east as strong conglomerates. On the right bank here and there the same beds appear, but there are Recent river-gravels mixed with limestone and

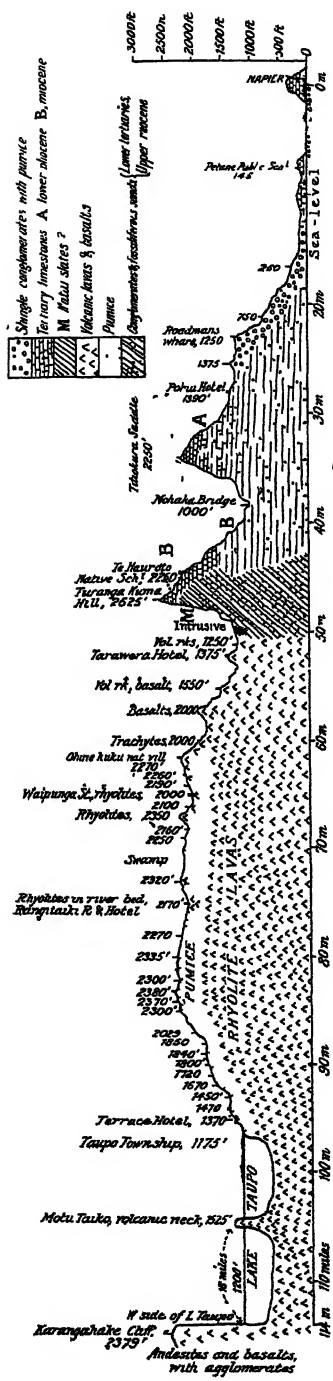


FIG. 1.—SECTION SHOWING COACH-ROAD, NAPIER TO TAUPO.

shells, and these may be mistaken for portions of the conglomerate series unless some care is taken to observe that the valley has been choked with shingle washing from the higher country at the back.

Leaving the Esk Valley, a long hill gives exposures of fine sand, which is in places fossiliferous. This sand about half-way up the hill becomes pumiceous, and in several places the whole exposure is a somewhat indurated fine pumice similar to what is met with among the shingle conglomerates at the Kidnappers. No fossil leaves, &c., were found by me, but in several other places the beds form a very good collecting-ground.

Proceeding towards the top of the hill near Eskmount, the conglomerates are again met with topping the highest hills on the one hand, whilst the limestone appears in several places, and along the road up to the twenty-mile stone the middle beds appear. Here the conglomerates top the hills on either side of the valley, whilst huge conglomerate blocks lie about the paddocks, and the whole country hereabouts is covered with conglomerates, alternating at times with fine sands mixed with pumiceous clays.

Up the hill leading to Carmichael's, conglomerates, fine laminated clays, sands, shingle, sands, and shingle cement are seen in descending order in great cuttings on the roadside. From the top of the hill (1,250 ft.) the conglomerates continue towards Pohui, the highest point of the road (1,375 ft.), being occupied by them half a mile or so beyond the roadman's whare.

Descending into the Pohui Valley, the conglomerates are replaced by hungry sands, and these continue as the characteristic rocks until crossing a small bridge leading up to the Pohui Hotel. Here nodular limestone appears in the blue clays, and fragments of broken shells are common, but it is difficult to determine their kind. Near the hotel limestone blocks are scattered about, and they appear to correspond to the lowest beds of the Napier series.

Titiokura Hill is made up of Miocene beds, and these are of extreme thickness,

as they are traceable from 2,250 ft., which is the height of the Titio-kura Saddle, to 1,000 ft. at the Mohaka Bridge, where the same kind of rocks appear as in the case of the nodular limestone near Pohui, the Miocene beds varying somewhat in character as the long hill from Mohaka to the top of Turanga-kuma (2,625 ft.) is reached. Here, at what is known as the Te Kooti Track, the Miocene beds are seen resting unconformably upon the Maitai slates, and from this place onward the slates and sandstones are the prevailing rocks as far as Tarawera.

A mile or two on the Napier side of Tarawera intrusive volcanic rocks are met with in several places. Up the Waipunga Valley intrusive rocks are common, and six miles beyond Tarawera rhyolites constitute the only rock by the roadside, and these continue for many miles in the direction of the Rangitaiki Hotel, or, rather, they disappear near the 68th milestone, where the swamp-area begins.

Runanga is at the 65th milestone. A mile or so from this place is a high hill, 3,200 ft. high, known as Otumakioi. It has a trig. station on the top, and there the sandstones appear very similar in appearance to the Permian sandstone of England. It seems to be connected with the Maitai slates, as these were exposed in one or two places on the hillside. The country, however, is so bush-clad that climbing becomes a difficult matter.

Immediately opposite Otumakioi, but to the north-east, is another hill or mountain, Piki-o-hiko-wera, which is composed entirely of volcanic rocks. From Runanga all the exposed rocks, whether on the roadside, in the bed of the streams, or forming the ranges that run to the north-west and north, are volcanic lavas, mainly trachytes and rhyolites. A mile or two along the valley that extends from Runanga towards the plateau extensive washings have taken place, and pumice terraces with sloping sides leading into the valleys make their appearance. This country of late years has been occupied as a cattle and sheep run, and the owner, in order to drain a large swamp-area that is the true watershed between the Mohaka and Rangitaiki Rivers, had a trench dug, so as to drain the water into the Waipunga Stream by way of a smaller stream that passes the roadman's house at Runanga. This drain was originally made about 4 ft. in depth and 2 ft. wide, but the breaking into the pumice has resulted in the formation of a huge gorgelike area nearly three-quarters of a mile long, 60 ft. or more wide, and very deep. The removal of the surface of rushes and *Sphagnum* has resulted in the washing-out of a gulch that can hardly be understood without inspection. The slightest increase in the rainfall causes the removal of great quantities of pumice pebbles, which fill up the entire area of what was at one time in the history of the district an extensive crater, the walls of which can be distinctly read.

In several places are volcanic hills or mounds, without craters, resembling similar structures such as may be seen to-day in the district where volcanic phenomena are active, particularly on the west of Ngauruhoe and the north-west of Ruapehu. This swamp extends for a number of miles, and to get to the Rangitaiki it is necessary to pass over the ridge or southern crater-wall, from which there is a gradual descent of about 200 ft. in a distance of two miles.

The Rangitaiki River basin is separated from the Mohaka basin by a range of hills, except towards the north-west, where a small stream from the swamp also drains into the Rangitaiki. A study of the surrounding country between the 73rd and 83rd milestones leads to the opinion that

at one time a series of lakes covered this area. The Rangitaiki River has its source in some old crateral lakes on the Loch Inver Station. Here trachytes are found in close proximity to the sandstones which top the low-lying hills that form the northern end of the Kaimanawa Mountains. The lakes seem to have been centres of explosive action, and at the place of outflow, where the water flows into the open country and takes the name of the Rangitaiki Stream, the rhyolites form a lip which has been cut through by the owners of the station by means of blasting, so as to assist in the drainage of the swamp and lake.

The country has few exposures of rock, but in a creek near the station already named both sandstones and the Maitai slates occur, just as a little lower down the volcanic rocks appear, although no intrusive rocks were met with.

Following down the Rangitaiki, which runs between high banks, there appear exposures of peat-lignites of some 9 ft. in thickness. These cover a large area between the upper stream and the Rangitaiki Hotel, a distance of some six miles. Whether the beds reappear below the hotel I do not know, but the exposures show that at one time a very large part of what is now pumice-covered country consisted of swamplike areas similar to what are met with and are now being drained in the vicinity of Runanga. The lignite material is made up of *Sphagnum*, stems of shrubs such as *Veronica* and *Fagus*, and a large variety of fibrous roots matted together into a compact mass. Overlying the lignite is pumice, very fine in structure, and without pebbles. It is not more than a few inches in thickness, and it appears to have been deposited by water. It is difficult to account for this covering of lignite or vegetable beds by a pumice-deposit, because the fact of a lignite-bed implies a long period of undisturbed growth and decay. It may be that the lignite-beds represent the old surface of the plain before the last great outpouring and spread of pumice, when the country as far as the 81st milestone contained a series of swamplike lakes that spread here and there among the hills forming the head-waters of the Rangitaiki, and even flowed at times over a saddle into the swamp-lakes that begin in the vicinity of Runanga. A low saddle from the Napier–Taupo coach-road to Loch Inver forms the dray-road to the station; and when viewing the topography of the country from one of the higher hills of the district it can be seen that the various lake-areas were at one time joined by low saddles that are not more than 300 or 400 yards in width. In some parts of the lignite-beds there is a thin band of pumiceous clay between the two main lignite-beds; but everywhere the pumice-beds overtop the lignites, just as the pumice to-day covers the whole surface of the Taupo Plateau.

Down the Rangitaiki River, ten miles or so from the coach-road, a series of rounded hills occur, and these run north-west as far as the track, which divides, one to Galatea and one to the Waiotapu Valley, across the Kaingaroa Plain. At this place there are the remnants of rocks that must at one time have formed an immense crater, the broken-down walls reminding one of old embattlements. It seems as if the country to the north-east of the 81st milestone must have sloped in the direction of Waipunga, and that the surplus waters, charged with pumice, were carried into the Mohaka River, and thence into the area of Hawke's Bay.

In a former paper (Trans. N.Z. Inst., vol. 37, p. 445) reference is made to the original drainage from Ruapehu and Tongariro at the time when the present Lake Taupo was the crater of an immense volcano. The suggestion is made

that the drainage from the mountains went in the direction of the present Rangitaiki. When this took place the series of lakes were in existence to which reference has been made. The whole of the Taupo country to the north was in process of being formed. It can be readily understood that swamp-areas would likely be formed within an area that had already been subject to volcanic forces.

From the hotel on the left bank of the Rangitaiki, Taupo Road, to Lake Taupo is twenty-three miles. A reference to fig. 1 will show that

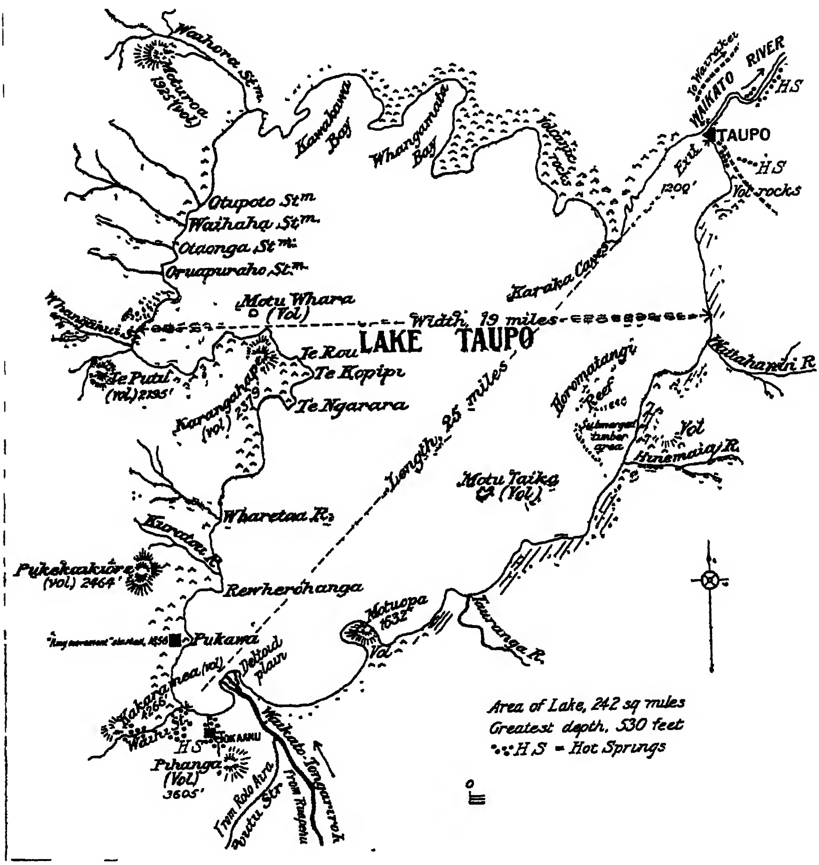


FIG. 2.—SKETCH-MAP OF LAKE TAUPO.

the plateau between the hotel and the lake presents two distinct areas of drainage. The entire area after passing a range of low bush-clad hills on the left is a mass of pumice of unknown depth, interspersed here and there with volcanic grit, magnetic iron, sand, and angular and rounded pieces of heavy rhyolite-andesite lavas that suggest water carriage without much wearing, because bedding is traceable in the pumice wherever washaways occur.

From the 80th to the 85th milestone the country to the south-east and north-west presents a high ridge, and this constitutes the line of separation

between Taupo Lake as a drainage-area and the drainage of what must be considered as a part of the Rangitaiki drainage-area. Taupo itself is only 1,200 ft. above sea-level, and Karangahape, the high headland on the western side, reaches only 2,379 ft., whilst thirteen miles from the lake (that is, at the 85th milestone), on the Taupo Road, the height is 2,380 ft. —in other words, the top of Karangahape is on a level with the highest portion of the plateau.

Taupo as a volcano was apparently much larger than it is as a lake. It would almost seem as if the long, high ridge between the 80th and the 85th milestones formed the eastern side of a great crater in which were many supplementary craters such as are seen to-day as centres of activity in places already named. In the earlier period of volcanic activity the whole country from the Kaimanawa Range to the ranges bounded in most places by the Main Trunk Railroad from the latitude of Ruapehu consisted of one immense lava-flow of similar volcanic material, and it is interesting to compare the height of some of the conelike hills with the heights of the country along the eastern and north-eastern side of Lakes Taupo and Rotokawa. The western and eastern portions of this once great sea of lava have merely left remnants of what they once were as centres of volcanic movement. Here and there a hot spring remains, but otherwise all active volcanic phenomena have long since disappeared, and the only portion that is really active at the present time is the great central line where so many traces of explosive eruptions are found.

The great explosive eruption at Taupo and Rotokawa, as also that at Pihanga Mountain, mark the largest and most disastrous of all those that have occurred in the North Island. The pumice thrown out spread over the country, mainly to the eastward, as far as Poverty Bay in the north and Hawke's Bay in the south, whilst the middle part of the Island was filled up to a great depth with pumice and other forms of volcanic ejectamenta. Pihanga's explosion was towards the north, where the crater-lip was blown right out, and is the counter of the Tarawera explosion, which was towards the south; in fact, the whole face of the country forming the central portion was altered by the explosions and the materials thrown out. The water that had drained into the Rangitaiki from the volcanoes to the south were diverted into the new Taupo crater, which, like Rotomahana, contained many traces of volcanic activity similar to what was seen in the latter basin after the Tarawera eruption; and, just as that basin has been slowly filling with water, so in the same manner, following what was an eruption at Pihanga, Taupo, and Rotokawa, immense quantities of *débris* were deposited over the country for many miles around the centres of explosion, so that watersheds were altered, drainage-areas diverted, swamp-areas replaced which before had been streams and tributaries, and finally provided a drainage-area of considerable size for the new crater that extended for thirty miles or more, and in which thousands of steaming places were to be found.

At this time there was no Waikato River such as we know it to-day, for the Waikato, from the spot where it leaves Lake Taupo as far as Orakeikorako, merely flows through a chasm or rift formed at the time of the Taupo explosion, but filled towards the crater-lake with pumice that raised the surrounding country several hundreds of feet in height. When the lake filled in course of time the water found a way through the chasm, and lowered the waters of the lake some 200 ft. or more. A subsequent

earthquake caused the Huka Falls and the attendant depression. the silica-cemented pumice in the vicinity being sheared as with a knife.

Lake Taupo at one period of its history was much larger than it is at present. The terraces on the west and east, the surface-characters of the slopes in the vicinity of the lake, and the various valleys that run for long distances towards the east at a gentle slope all suggest an area once covered with water. At the northern and southern ends of the lake hot springs and many other evidences of volcanic phenomena occur, and these extend underneath the waters of the lake from a good distance from the shore. Hot springs, fumaroles, &c., are equally abundant 600 ft. or more up the hills towards Tauhara Mountain at the northern end, and even higher at the southern end, where at Waihi only a few weeks ago a hillside from the fumarole-area broke away and slid into the lake.

The activities of Rotomahana and its vicinity such as have been manifested since the eruption, particularly to the southward, correspond in a remarkable manner to what took place to the north of Taupo following the eruption there. In pursuing one's inquiries into this interesting subject one is struck with the fact that the surface-features of the country must have been modified as much by earthquakes as by volcanic agencies; but the key to the true interpretation of all the phenomena to be met with at Waiotapu, Rotokawa, Wairakei, Taupo North and South, and Te Mari is to be found in the study of the phenomena connected with the Tarawera eruption and the subsequent events that have taken place in the district. Fig. 2 shows merely the present size and boundaries of Lake Taupo, with such information as I have been able to gather during my frequent visits to the district.

Earthquakes have caused marked changes in the vicinity of Taupo. Cussen reports that on the 28th August, 1883, a schooner was lying at the small wharf where the Waikato leaves the lake, when a sudden fall of 2 ft. took place. In about twenty minutes the river rose again to its former level. Mr. Enoch Hallet, who was present at the time, informed me that between 1 and 2 o'clock the same afternoon, as the river fell, two members of the Constabulary stationed in the township—namely, Major Smith and Sergeant Miles—were bathing in a warm spring called Waiarika, situated on the bank of the Waikato River, about a mile from the lake. Next the river the bath was fenced about with stones, and it stood about 2 ft. above the level of the water. Suddenly the bath became cold, and the bathers were astonished to find that the river had risen to a level with the bath. It remained in this state for about five minutes, and then suddenly returned to its former position.

In August, 1895, a very severe earthquake took place in East Taupo, and the public road in places was entirely destroyed. The pumice cliffs were much altered, and the isolated hill known as Manguaume, about three miles to the eastward of the lake, was split in parallel lines that ran north-east and south-west. Around the lake, but more particularly towards the east and north-east, are long deep valleys, consisting of main valleys and branching ones. It is difficult to account for the formation of these, unless we suppose that the lake was much higher and, of course, larger than it now is. The Rev. Mr. Fletcher, of Taupo, suggests that a subsidence of a large area in the lake took place, or that the wearing-away of a barrier in the river caused the deep, regularly cut valleys. But the same kind of valley is common over the greater portion of the Taupo Plateau, and some of the valleys slope in the direction of the Bay of Plenty. The more likely

reason is that a sudden uplift took place of the country to the east and north-east of the plateau, which affected the entire area extending as far as Rotorua.

In riding over the district one is impressed with the fact that the surface-features suggest changes of comparatively recent date. Bidwill, in 1839, when travelling between Tauranga and Taupo, refers to traces of dead and burnt timber over a large extent of country. At that time no manuka (*Leptospermum scoparium*) was to be found between the Rangitaiki and Lake Taupo, and, in fact, there was no manuka between Tauhara Mountain and the lake so recently as 1869. Around the base of Tauhara, on the northern slopes, and reaching for several miles, are scores of charred totara-trunks that must have been of enormous size. No Native has any knowledge of the area being covered with forest, but the logs remain to show that at some former time the country was bush-clad, and extended apparently in the direction of the Opepe Bush. Even at the present time the Taupo Plain is only just beginning to have the semblance of a cap of vegetation.

The entire country has been subject to many disastrous explosions and earthquakes, so that the physical changes have been of frequent occurrence. Some of the old craters are possibly overwhelmed along the line where old crateral walls can be traced along the ridge that now separates the Waikato and the Rangitaiki drainage-areas. As already remarked, the growth of manuka on the plateau only began in the "seventies." Tamati te Kurupae, the present leading chief at Taupo, recollects well when the manuka first appeared, and so rapidly did it spread that it drove many Natives from their settlements, as they were unable to grow crops as heretofore. Neither Bidwill nor any other writer that I can discover makes reference to the *Leptospermum* as growing freely, and which is now so abundant in the district. This seems to me to imply that the surface of the plateau is comparatively new, and the limited vegetation seems to support this view. A pumiceous surface such as the Taupo Plateau would take a long time to become the abode of even the lowest forms of vegetation, except within the area of the swamps.

The legends of the Natives are most suggestive in connection with the surface-changes on the plains, implying differential movements that altered the flows of the rivers, and even caused jealousies to spring up between them. A long time ago, so runs the legend as told to me by Tamati te Kurupae, the leading Taupo chief to-day, a serious quarrel arose between Waikato and Rangitaiki as to which had the greater mana. Rangitaiki urged that he was the greater and more important among the rivers, but Waikato replied, "No; I am chief; but if you think yourself stronger and better let us put the matter to the test by seeing which of us will first reach the ocean." Rangitaiki derided the words of Waikato, and many angry scenes were witnessed, but at last it was decided to put the matter to the test. The race began. Rangitaiki started from the swamps, and Waikato from Lake Taupo. Soon the latter river reached the Aratiatia Rapids, but becoming anxious about the Rangitaiki, his rival, he asked Puato (a small stream entering the Waikato on the right bank) if he had seen Rangitaiki. Puato replied that Rangitaiki was moving rapidly towards Waikato, hoping to destroy him. Waikato made strenuous effort to move away from his rival. At Orakeikorako Waikato sent Tori-patutahi (another stream entering the river on the right bank) to go and see what had become of Rangitaiki. Tori-patutahi returned in haste and said that Rangitaiki

was close at hand. This news caused Waikato to alter his course to the sea, and thus he was able to outpace Rangitaiki, who, wandering through the country, lost his way in the Whakatane Swamp, which showed how inferior he was in his mana to Waikato, whose name means "a great chief or leader of the people."

This legend is most suggestive as showing the likely changes that took place along the ridge that separates the drainage-areas of Waikato and Rangitaiki to the north of Mount Toruhara. There is no doubt whatever that the surface of the country extending from Rotokawa to Orakeikorako and thence on to Waiotapu has undergone changes within recent times. It is possible that the Puato and Tori-patutahi Streams flowed into the Rangitaiki before the great eruption at Taupo, and even up to the time when the rift occurred that now forms the Waikato itself from the place where it leaves Taupo Lake down to Orakeikorako. An imaginative people like the Maori personifies the changes or movements that take place in stream and mountain and bush, and the very fact that Puato and Tori-patutahi were sent as messengers to look after Rangitaiki implies a change of flow in these streams, or at least a modification in the conditions of the country.

A study of the surface-features of the Kaingaroa Plain to-day shows that the line of movement was to the north-west, and the exposures of the rocks suggest a marked depression to the northward of the fault that runs across the plateau in a north-west and south-east direction about sixteen miles from the lake. A reference to fig. 1 will explain this point. Tauhara Mountain is only 3,600 ft. above sea-level, and Lake Taupo is 1,200 ft. The highest point on the plateau is about 2,530 ft. There are no exposed lavas nearer than Manganamu and Tauhara. The old water-valleys show nothing more than pumice and volcanic ejectamenta, except at King's, near Opepe, where traces of volcanic rocks *in situ* are said to occur. Thus the lavas towards the Rangitaiki are much higher than are found between Opepe and Lake Taupo, so that unless there has been a big depression between Opepe and the lake, of 1,000 ft. or more, it is difficult to see how there could have been a connection between the lavas from Tauhara and those found at Loch Inver and Runanga.

A survey of the whole of the volcanic area is badly wanted. Every volcanic orifice should be located, and the country mapped to show that the present line of volcanic activity is only one aspect of the phenomena that have taken place over a long period of time to bring about the present surface-features of the country. Isolated inspection is insufficient to formulate opinions as to the history of the surface-changes of the volcanic area and the probable duration represented by the volcanic rocks to be found in the district; but the events at Tarawera in 1886 suggest a line for observation. What took place at Rotomahana has likely taken place in a score of other places, and by placing the facts side by side, and studying the growth of vegetable-life within areas that appear to have been acted on by outbursts, as exemplified in lakes of depression, it may be possible to read far into the past, and even to suggest something as to the future.

ART. XXXV.—The Coalfields of West Nelson; with Notes on the Formation of the Coal.

By J. HENDERSON, D.Sc., A.O.S.M.
Communicated by Professor James Park.

[Read before the Otago Institute, 4th October, 1910.]

AT the beginning of the coal period what is now west Nelson consisted of the same series of earth-blocks as now. These blocks had been subjected to denudation, and parts of the elevated blocks had been reduced to the same level as the depressed blocks; consequently, when depression of the whole took place, conglomerates and sandstones were deposited not only on those blocks with a tendency to sink, but also on the lower portions of those blocks with a tendency to rise.

A pause in depression permitted vast swamps and forests to envelop the coasts; it is possible that the centres of the valleys were still under water. Further sinking caused the vegetation to be smothered by deposits, and repetitions of the processes have produced other seams. The gradual filling-in of the central deeper portions of the graben valleys would permit of the higher seams overlapping the lower in that direction, while the sinking of the land would produce overlap in the other. It is thus possible that the higher seams may extend right across a valley, while the lower thin out toward the centre; perhaps all the seams so thin out. Where the main drainage-channels crossed the vegetation-fringe the coal-seams are likely to thin out and become impure. Again, it is conceivable that different portions of the coastal fringe, by reason of differential sinking and differential filling, would become fit for vegetable growth at different times. When all is considered, it seems probable that the coal should occur as seams thinning out in all directions, and that the beds should overlap each other in a great variety of ways. The coal has not yet been sufficiently worked to prove these contentions, but the seams of Denniston, Reefton, and Greymouth appear to conform entirely with them.

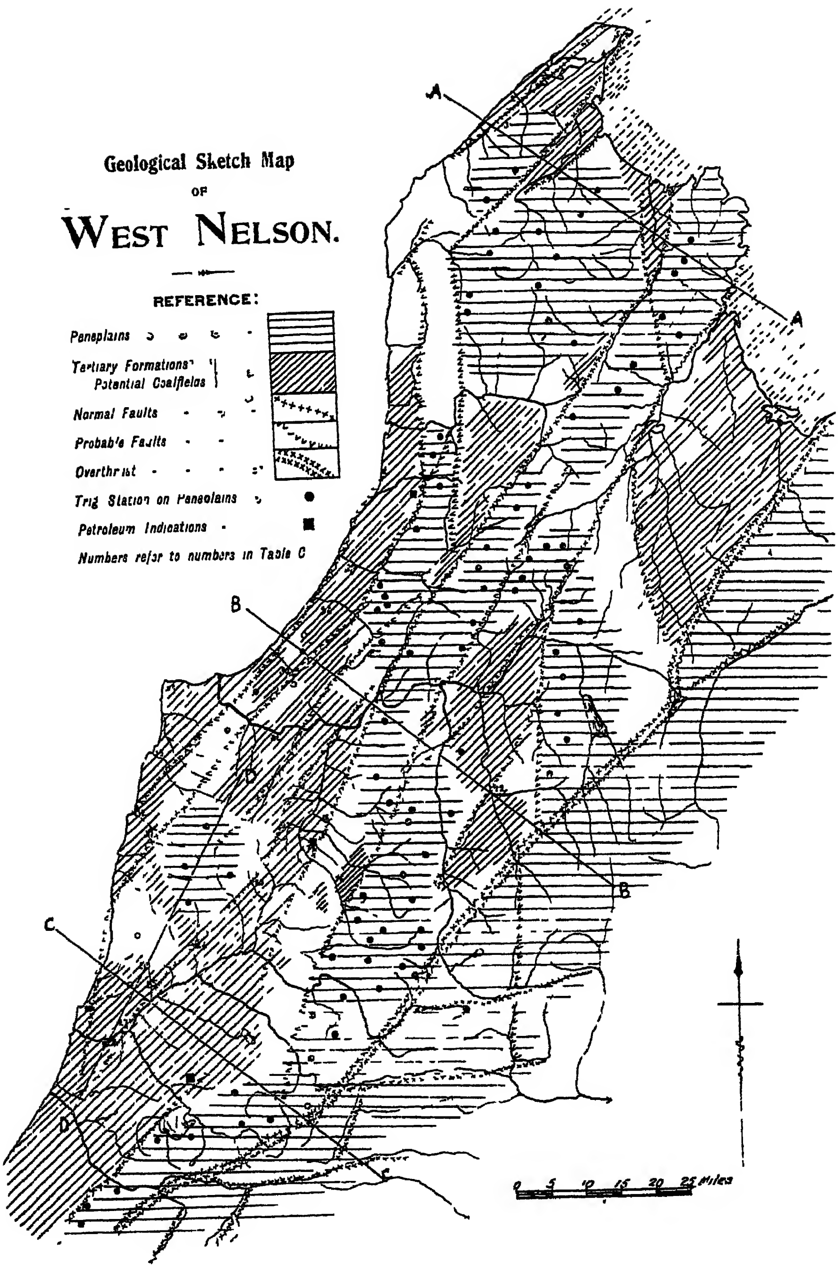
The hypothesis which considers coal-seams as altered accumulation of drift vegetable matter finds support in west Nelson, in that the coal frequently rests on hard rock without the interposition of fireclay; further, the fireclay bands occur indifferently at the bottom or the top of the coal-seams. Again, water-worn pebbles occur in the coal at Point Elizabeth. The distribution of the seams is perhaps more readily explained by this than by the growth-in-place hypothesis. On the other hand, if the seams have been formed from drift some at least should occur intercalated with marine beds. This does not seem to be the case, and the beds immediately associated with the coal appear to be either estuarine or lacustrine.

COALFIELDS.

The thrusting-up of what are now the peneplains, but what in Miocene times were base-levelled islands, through the surrounding coal-measures permits of a somewhat arbitrary division of the coal-areas into coalfields.

The Whakamarama* Coalfield comprises the coal lying to the west and north of the Whakamarama peneplain. It may be conveniently subdivided

* Hochstetter: "New Zealand," pp. 58, 84, 85. Hector: Geol. Surv., No. 4, p. 18 et seq.; No. 19, pp. ix–xiii. Cox: Geol. Surv., No. 15, pp. 71–73. Park: Geol. Surv., No. 20, pp. 52–57, 200–5, 237–41. Mackay: Papers and Reports relating to Minerals, 1900, C.-6, pp. 1–5.


Geological Sketch Map
of
WEST NELSON.
REFERENCE:
Peneplains
Tertiary Formations Potential Coalfields
Normal Faults
Probable Faults
Overthrust
Trig Station on Peneplains
Petroleum Indications
Numbers refer to numbers in Table C
A
A
B
B
C
C
D
0 5 10 15 20 25 Miles

into two portions—that lying between the Aorere and Wanganui faults and resting on a northern extension of the Whakamarama earth-block, and that lying to the west of the Wanganui fault and fringing the coast as far south as the Big River. Only the edge upturned by the Wanganui fault of this, the Wanganui subfield, occurs above sea-level. The composition of the coal of the Wanganui section is shown in analyses 1 and 2, Table C, while analyses 3, 4, and 5 indicate the composition of the coals of the Pakawau section. Coal has been worked at West Wanganui, Pakawau, and Puponga. The seams appear to be numerous, and up to 8 ft. in thickness.

The Taitapu* Coalfield occupies the floor of Golden Bay, and the coal-measures, extensively faulted, extend southward along the valleys of the Aorere and Takaka. The seams have been worked only at Motupipi, and are there up to 4 ft. in thickness. Analyses 6 and 7, Table C, show the composition of the coal.

The Whakatu† Coalfield is limited by the Motueka, Sherry, and alpine-overthrust faults. It extends beneath the Moutere gravels in the valley of the Motueka, and beneath the waters of Blind Bay and part of Tasman Bay. Coal outcrops at various points in the Motueka Valley, in the Tadmor, at Big Bush, and near Nelson, while carbonaceous shales occur in D'Urville Island. Coal has been worked near Nelson, and reaches up to 11 ft. in thickness, but is here crushed by the alpine overthrust. The composition of the coals is shown by analyses 8, 9, and 10, Table C.

The Kawatiri‡ Coalfield occupies the Kawatiri depression. It is divided into three parts by the Motueka and Tutaki faults. Of these, the most important is the central, or Mangles, section, in which the coal is mined for local requirements at Longford and the Owen. The Matiri and Glenroy subfields are northern and southern continuations respectively of the Mangles section. The seams of the Kawatiri Coalfield range up to 30 ft. in thickness. Their composition at various points is shown by analyses 11, 12, and 13, Table C.

The Oweka§ Coalfield occurs in the basins of the Inangahua and Grey Rivers, and probably extends as far south as Ross, beneath the flats of the Taramakau and Hokitika Rivers. The main central portion of the field lies in a trough between the Inangahua and Mawhera faults, and stretches from Inangahua Junction to Ross. A series of outliers cap the hills to the east from Larry's Creek to Big River, and again near Lake Kanieri. These outliers are not so deeply foundered as the main portion of the coal-field. The seams of this field range up to 60 ft. in thickness, and have been worked at several points near Reefton. Analyses 14, 15, 16, 17, 18, 22, 23, and 24, Table C, indicate the composition of the coals.

* Hochstetter: "New Zealand," p. 461. Park: Geol. Surv., No. 20, pp. 238–41. Mackay: Papers and Reports relating to Mining, 1896, C.–11, pp. 13–21. Bell: N.Z. Geol. Surv. Bull. No. 3 (n.s.), pp. 49–61.

† Hochstetter: "New Zealand," p. 461. Mackay: Geol. Surv., No. 12, pp. 120, 121, 129, 130; Papers, &c., relating to Mining, 1896, C.–11, pp. 27–30. Park: Geol. Surv., No. 19, p. 80.

‡ Cox: Geol. Surv., No. 16, pp. 5–9. Park: Geol. Surv., No. 19, pp. 79, 80. Mackay: Geology of S.W. Nelson, pp. 57, 59, 61.

§ Mackay: Geol. Surv., No. 15, pp. 140–50; Geology of S.W. Nelson, pp. 57–61. Cox: Geol. Surv., No. 10, pp. 78–80. Bell: N.Z. Geol. Surv. Bull. No. 1 (n.s.), pp. 78–81. Morgan: N.Z. Geol. Surv. Bull. No. 6 (n.s.), pp. 102–12. Campbell: Geol. Surv., No. 11, p. 32.

The Greymouth* Coalfield is divided into three sections by faults. The central Brunner section rests on the southern extension of the Paparoa earth-block, and Point Elizabeth and Blackball sections are downfaulted on either side. The seams are very extensively worked, and analyses 25 to 30, Table C, show their composition.

The Westport† Coalfield is analogous in structure to the Greymouth one. The central Mount Rochfort Coalfield lies on the northern extension of the Paparoa earth-block, and extends as far north as the Mokihinui. The Orikaka section, to the east, is downfaulted between the Orikaka and Mawhera faults. The coastal section, to the west, extends from the Punakaiki to north of Westport, and underlies the sea for an unknown distance. The coal of Mount Rochfort section is mined at several points, and the seams range up to 60 ft. in thickness. Analyses 32 to 37, Table C, show the compositions of the coals.

The Karamea‡ Coalfield extends from the Mokihinui to the Heaphy. Little is known of this field. Analysis 38, Table C, is of a coal from a 7 ft. seam in this field.

Structurally, the Whakamarama and Taitapu Coalfields may be considered as forming an anticline,§ with the Pakawau section as the crown and the Wanganui and Taitapu sections as the limbs of the anticline. This anticline, which plunges to the north, is really the northern section of an elongated dome, formed by the thrusting-up of the Whakamarama earth-block through the coal-measures. This dome was never complete, as the coal-measures never covered the earth-block entirely. The Aorere and Wanganui faults probably grade into flexures in depth and also towards the north. A similar anticlinal structure prevails in the Greymouth and Westport fields, and probably also at the southern end of the Whakamarama earth-block in the Karamea field. The Whakatu field has probably a synclinal structure sloping to the north, and this structure has been brought about by the dragging-up of its edges by faulting. The Kawatiri field is probably boat-shaped for similar reasons; but the symmetry of the basin has been destroyed by the Motueka and Tutaki faults, which leave the Matiri and Glenroy sections as elevated shelves. The structure of the Oweka field is in the main monoclinal, although, if the Orikaka subfield in the north and the Blackball subfield in the south be regarded as parts of this field, the structure becomes synclinal at these points.

Composition.

It is generally admitted that, omitting cannel coal, &c., all coals have been formed from vegetable matter of initially similar composition. The transformation of this vegetable matter is due to a fractional distillation, and the quality of the resulting coal depends on its relative completeness. The most generally recognized factors controlling this transformation are time, heat, and crustal movements.

* Haast: Geology of W. Nelson, p. 104 *et seq.* Hector: Geol. Surv., No. 4, pp. 24–27; No. 20, p. xiii; No. 21, p. xxxviii; No. 9, p. iv. Cox: No. 10, p. 81. Campbell: No. 11, p. 31. Mackay: Geology of S.W. Nelson, pp. 57–61.

† Haast: *Loc. cit.*, p. 113. Hector: Geol. Surv., No. 4, pp. 22–24; No. 9, p. iii; No. 18, p. 156; No. 21, p. xxxiii. Cox: No. 10, pp. 106–20. Denniston: No. 10, pp. 121–71. Mackay: No. 18, p. 161 *et seq.*; No. 21, pp. 76–97.

‡ Haast: *Loc. cit.*, p. 116. Bell: N.Z. Geol. Surv., 2nd Ann. Rep. (n.s.), pp. 7–9. Webb: *Loc. cit.*, pp. 24–27; 3rd Ann. Rep. (n.s.), pp. 21, 22.

§ Hector: Geol. Surv., No. 19, p. x.

It is important to distinguish between the effects of natural distillation and atmospheric weathering. The following table shows the progressive effect of natural distillation :—

Table A.

Fixed Carbon.	Hydro-carbons.	Water.	Ash.	Locality.	Reference.
38·26	40·51	20·41	0·82	Charleston ..	Col. Lab., 29.
39·16	40·63	18·46	1·75	Giles Creek ..	J. Henderson.
42·70	41·00	13·70	2·60	Motupipi ..	Col. Lab., 41.
42·13	41·72	10·27	5·88	Golden Ridge ..	" 41.
46·60	43·32	8·87	1·21	Burke's Creek	" 28.
48·59	43·15	4·84	3·42	Seddonville ..	" 41.
49·15	46·75	3·20	0·90	Blackball ..	" 37.
56·43	39·68	2·10	1·87	Denniston ..	" 41.
58·69	39·26	1·00	1·05	Millerton ..	" 41.
76·38	19·25	0·93	3·44	Paparoa ..	" 38.
90·90	5·10	0·80	5·20	Fox's River ..	" 35.

It will be noted that the change from the brown coals to the best of the sub-bituminous is accompanied by a diminution of the water and an increase in both fixed carbon and hydrocarbons. Further change takes the form of an increase of fixed carbon at the expense of the hydrocarbons, the small percentage of water being decreased very slowly. With atmospheric weathering, on the other hand, the percentage of water is increased; but the main change takes the form of a decrease in the hydrocarbons, causing an apparent increase in the fixed-carbons percentage. A comparison of the odd numbers with the next following even numbers in Table B will make this clear as far as sub-bituminous and bituminous coals are concerned.

Table B.

	Fixed Carbon.	Hydro-carbons.	Water.	Ash.	Locality.	Reference.
1	54·31	33·81	10·46	1·42	Burke's Creek ..	J. Henderson.
2	42·42	49·20	7·28	1·10	Same seam ..	Col. Lab., 42.
3	54·18	34·69	9·54	1·59	Blackball ..	" 22.
4	49·15	46·75	3·20	0·90	" ..	" 37.
5	50·00	38·70	5·80	5·50	Rise, Point Elizabeth	" 38.
6	44·08	43·00	5·85	7·07	Dip, Point Elizabeth	" 41.
7	52·40	38·90	6·70	2·00	Mokihinui ..	" 38.
8	48·59	43·15	4·84	3·42	" ..	" 41.
9	66·12	28·82	4·25	0·81	Denniston ..	" 11.
10	56·43	39·68	2·10	1·87	" ..	" 41.

A glance at Table C, on page 305, will show that the coals of west Nelson have a very wide range of composition, and it is to this wide range in the qualities of the various coals that the confusion of classification of the beds in the past has been mainly due.

Von Hochstetter* divided the coals of west Nelson into two series—Mesozoic and Tertiary—mainly on account of the difference in composition. Von Haast† does the same. Cox‡ divided the coals between the Lower Greensand and Cretaceo-tertiary on stratigraphical grounds; but, evidently influenced by the difference in composition, Hutton§ placed the coals of Nelson and Motupipi in the Oamaru series, and those of Pakawau, Wangapeka, Westport, Greymouth, and Reefton in the Amuri series, of Cretaceous age. Hector‖ has pointed out the anomalies connected with this classification, and has shown that, as far as west Nelson is concerned, the palaeontological evidence upon which Hutton relied for his classification was very incomplete. Park¶ at first recognized two coal-horizons, but now, as the result of later investigation, places the Wanganui and Inangahua, Westport, and Greymouth coals in the Oamaru series, of Lower Miocene age. Von Ettingshausen,** from an examination of the fossil plants, considered the strata at Pakawau, Wangapeka, Greymouth, and Reefton of Cretaceous age. Hector†† placed all the coals of west Nelson at the base of his Cretaceo-tertiary, but considered that the coals occur in an upper and a lower horizon. Mackay‡‡ placed the seams in the Cretaceo-tertiary, and did not express any opinion as to their occurrence in different horizons.

From the above it will be seen that very considerable difference of opinion has existed as to age and relationships of these beds.

The writer will attempt to show that the coal-seams may occur in one series of beds. Wherever the basement rock of the coal series is exposed the coal-seams rest either hard on the basement rock or on sandstones and conglomerates immediately overlying it. Such is the case in the Pakawau field, at Motupipi, Nelson, the Owen, Reefton, Charleston, Denniston, and other points. In the Greymouth field the semi-anthracites of Paparoa, the sub-bituminous coals of Blackball, and the brown coals of Moonlight Creek all lie very near the basement slate.

At Point Elizabeth the rocks are downfaulted, and the coal rests upon a considerable thickness of sandstone and shale. These lower beds may possibly represent the coal-measures of Mount Davy. At West Wanganui the coal overlies sandstone, &c., but the basement rock is nowhere visible. These coals have been downfaulted, as is indicated by the difference in strike of the comparatively elevated outliers near Golden Blocks, and there is nothing to show that the West Wanganui coals overlie these or the Pakawau coals.

Again, with the seams at Moonlight, Blackball, and Paparoa, which are taken in ascending order of elevation and carbonization, it is difficult, if not impossible, to account for their relative positions except on the assumption that they all belong to the same horizon and owe their present positions to faulting, and their various compositions to different distillation-conditions. Again, in no section do the brown or sub-bituminous coals actually overlie the bituminous seams, nor do the limestones—which at

* Hochstetter: "New Zealand," pp. 58, 59, 85.
† Haast: Geology of W. Nelson.
‡ Cox: Geol. Surv., No. 15, pp. 71–73; No. 16, pp. 5–8.
§ Hutton: Trans. N.Z. Inst., vol. 22, p. 387.
‖ Hector: Geol. Surv., No. 21, p. xxxv.
¶ Park: "Geology of New Zealand," 1910, p. 293.
** Von Ettingshausen: Trans. N.Z. Inst., vol. 23, p. 241.
†† Hector: Geol. Surv., No. 18, p. xxxii *et seq.*; No. 21, p. xxxv *et seq.*
‡‡ Mackay: Geology of S.W. Nelson, pp. 57–61; Papers and Reports relating to Minerals and Mining, 1900, C.-6, p. 4.

many places overlie, perhaps unconformably, the so-called upper seams—at any place overlie the lower bituminous seams. All these things point to the conclusion that the coals of west Nelson belong to one series, of what age is here immaterial. Some other agency than time must, then, be looked for to explain the differences in composition of the coals.

That heat is competent to produce all the changes in coal-composition is well known. Its effects are well shown at Malvern,* where a brown coal has been altered by a volcanic dyke. Such action, however, is purely local, and cannot explain the varieties of coal in west Nelson. Again, the deep burial of coal beneath other rocks, and the consequent increase of temperature, greatly hastens the distillation process. Such a theory is, however, quite inapplicable to west Nelson, where none of the coal-measures are, or appear to have been, deeply buried, and where the occurrence of the more highly carbonized coals on the higher levels seems rather to contradict the theory.

Considering, then, crustal movements: these no doubt have great influence both from the pressure exerted and the heat engendered thereby. Probably the anthracite of Fox's River and the plumbago of Pakawau† have been produced by the action of great faults. But if such be the controlling factor of this problem it is to be expected that the coal near Nelson, which is actually inverted and entirely crushed by the alpine overthrust, would be highly carbonized. It actually contains 53 per cent. of fixed carbon and 10 per cent. of water. Again, the coals of Blackball and Paparoa, separated by a fault, which presumably affected them equally, contain 50 per cent. and 76 per cent. of fixed carbon respectively. Evidently crustal movements are incompetent to account for the variations in composition of the coals.

Time, heat, and pressure have been shown to be inadequate of themselves. Another condition controlling the rate of distillation is the ready escape of the distillation volatile products. These volatile products would have opportunity to escape if the overlying strata were porous or fissured. Porosity in a rock will have little influence where great thicknesses are concerned. Great thicknesses of porous rock do not, however, overlie the coals of west Nelson, the principal overlying rocks being mudstones, and wherever these have been wholly or in part removed the coals are highly carbonized.

Applying this hypothesis to the west Nelson coalfields, we find that in the Whakamarama field the coals of the Pakawau section occur in conglomerates capping the tops of the ranges, the upper more impervious mudstones and limestones, which at one time probably covered them, being removed. The coals are highly carbonized, but on the western dip of the anticline, and to the north where it plunges, the overlying impervious beds are still in existence, and the coals merge into sub-bituminous and even brown coals. The Taitapu field has always been depressed, and the overlying impervious covering is being added to, hence the coals are brown coals. Similarly, in the Whakatu field the main central portion of the field will contain brown coal, although round the edges of the basin coals of all qualities may be found, the degree of carbonization depending on local circumstances. In the Kawatiri field the bulk of the coals will be bituminous, but in parts of the Mangles section and towards the west generally the coals may grade to brown coals beneath the limestones, &c.

* Evans: Trans. N.Z. Inst., vol. 31, p. 557.
† Cox: Geol. Surv., No. 15, p. 71.

The coals of the eastern Oweka field are more elevated than those in the central section, and the upper beds of the measures have been removed. Thus the coals are superior to those of the central portion, which in turn grade from sub-bituminous on the east to brown coals on the west. In the Greymouth field the central elevated ridge carries semi-anthracites to bituminous, the degree of carbonization decreasing towards the south as the elevation decreases. South of the Tyneside the coals will probably be sub-bituminous, as are those of Blackball and Point Elizabeth. In the latter place mudstones and limestone overlie the coal. Similarly, in the Westport field the coals of the Mount Rochfort plateau decrease in carbonization toward the north, where they will be overlaid in depth by mudstones and become sub-bituminous or brown coals. The seams of the coastal section are likely also to be brown coals, while those of the Orikaka section will grade from sub-bituminous to bituminous according to local conditions. The anthracites of Fox's River, which may be included in the coastal section, are probably of purely local occurrence. Only brown coals have hitherto been reported from the Karamea field, but it seems feasible to suppose that bituminous coals may occur on some elevated ledge.

From the above considerations, and from the analyses shown in Table C, the following table may be prepared :—

Field.	Section.	Analyses.	Quality of Coal.
Whakamarama	Wanganui ..	1, 2, and 3 ..	Sub-bituminous to brown.
	Pakawau ..	4 and 5 ..	Bituminous to sub-bituminous.
Taitapu ..	..	6 and 7 ..	Brown.
Whakatu ..	..	8, 9, and 10 ..	"
Kawatiri ..	Matiri ..	..	Bituminous (?).
	Mangles ..	11	Bituminous to sub-bituminous.
	Glenroy ..	12 and 13 ..	Bituminous to brown.
Oweka ..	Eastern ..	14, 15, and 16 ..	Sub-bituminous.
	Central ..	17, 18, 22, 23, and 24	Sub-bituminous to brown.
Greymouth ..	Blackball ..	25	Sub-bituminous.
	Brunner ..	26, 27, 28, and 30	Semi-anthracitous to bituminous.
	Point Elizabeth	29	Sub-bituminous.
Westport ..	Orikaka ..	19, 20, and 21 ..	Sub-bituminous to brown.
	Mount Rochfort	35, 36, and 37 ..	Bituminous.
	Coastal ..	31, 32, 33, and 34	Brown.
Karamea ..	..	38	"

Not even the roughest estimate of the quantity of coal available in west Nelson can be given. This is due in part to lack of data, but principally to the irregular distribution of the seams or lenses of coal throughout the measures and the rapidity with which the thickness of the seams vary. At Denniston only one-tenth of the area of coal-measures contains workable coal. There is, however, little doubt but that many hundreds of

millions of tons are available. The bulk of this will consist of brown coals in no wise superior to the brown coals of the rest of New Zealand. Of the remainder the greater proportion will be sub-bituminous in quality. The comparatively small areas containing bituminous and anthracitous coals are elevated and geologically accessible, and because of this the quantities of coal they contain are approximately known.

Table C.

—	Fixed Carbon	Hydro-carbons.	Water.	Ash.	Sulphur.	Locality.	Reference.
1	35·76	43·63	15·40	4·21	3·86	Turimawiwi ..	Col. Lab., 25.
2	41·40	46·25	5·65	6·70	0·51	Patarau ..	,, 37.
3	47·80	42·23	5·42	4·55	0·88	Taitapu ..	,, 37.
4	59·53	32·19	5·18	3·10	0·70	Pakawau ..	,, 39.
5	52·50	40·20	5·90	1·40	1·92	Puponga ..	,, 36.
6	42·70	41·00	13·70	2·60	5·66	Motupipi ..	,, 41.
7	31·87	38·66	14·09	15·38	2·48	Takaka ..	,, 41.
8	53·59	33·80	10·20	2·41	..	Enner Glynn	,, 30.
9	44·35	31·78	21·27	2·60	3·13	Tadmor ..	,, 15.
10	59·16	30·04	6·12	4·68	..	Motueka ..	,, 33.
11	51·20	40·20	2·80	5·80	0·36	Longford ..	,, 38.
12	59·60	33·50	1·10	5·80	0·41	Glenroy ..	,, 38
13	50·11	29·76	15·12	5·01	..	Maruia ..	,, 29.
14	61·85	27·10	7·10	3·95	1·37	Ross ..	,, 41.
15	48·00	35·27	1·02	15·70	2·60	Kanieri ..	,, 39.
16	56·18	32·24	9·61	1·97	..	Murray Creek	,, 22.
17	42·42	49·20	7·28	1·10	3·89	Burke's Creek	,, 42.
18	56·98	31·37	9·57	2·18	..	Capleston ..	,, 22.
19	45·00	38·00	13·60	3·40	3·19	Orikaka ..	,, 39.
20	48·14	32·20	17·40	2·26	..	Berlin's ..	Sydney Fry.
21	64·06	11·59	10·14	14·21	..	Hawk's Crag	Col. Lab., 29.
22	39·16	40·63	18·46	1·75	0·41	Giles Creek ..	J. Henderson.
23	41·58	35·79	20·21	2·42	..	Little Grey ..	Col. Lab., 29
24	39·23	30·30	20·06	10·41	..	Slaty Creek ..	,, 29.
25	49·15	46·75	3·20	0·90	3·68	Blackball ..	,, 37.
26*	76·38	19·25	0·93	3·44	0·27	Paparoa ..	,, 38.
27†	59·23	33·33	2·11	5·33	3·36	North Brunner	J. Henderson.
28	58·00	37·83	0·37	3·80	1·96	Tyneside ..	Col. Lab., 38.
29‡	50·79	38·23	7·90	3·08	0·44	Point Elizabeth	,, 38.
30	59·27	35·34	2·34	3·05	0·28	Mount Davy	,, 41.
31	90·90	5·10	0·80	5·20	..	Fox's River ..	,, 35.
32	34·26	31·76	20·18	13·80	..	Brighton ..	,, 29.
33	38·26	40·51	20·41	0·82	..	Charleston ..	,, 29.
34	26·83	35·31	18·24	19·62	..	Cape Foulwind	,, 29.
35*	56·43	39·68	2·10	1·87	1·70	Denniston ..	,, 41.
36*	58·69	39·26	1·00	1·05	4·11	Millerton ..	,, 41.
37	59·35	38·20	1·95	0·50	4·38	Westport-Stockton	,, 40.
38§	52·40	38·90	6·70	2·00	3·83	Mokihinui ..	,, 38.
39	38·20	39·60	19·10	3·10	4·00	Karamea ..	,, 37.

* Mean of five. † Mean of seven. ‡ Mean of eleven. § Mean of sixteen.

Petroleum.

In west Nelson traces of oil are found at Karamea, Reefton, Dobson, and Kotuku. At Reefton the oil occurs in connection with certain shales underlying the coal. As pointed out by Morgan and Webb,* the source of the oil is undoubtedly the beds of the coal series. At Karamea and Reefton the shales and claystones which carry the oil are upturned by powerful faults, and the structure is synclinal.

At Dobson the bore from which the oil issues penetrates the western limb of the Brunner anticline. Between this bore and the crest of the anticline runs a branch of the great Mount William fault, to the west of which the oil will occur. At Kotuku the oil-permeated gravels lie over the northern continuation of the Ross fault, and it seems feasible to suppose that these supplies of petroleum are soaking up along this fault. The structure of the underlying coal-beds will be monoclinal.

Summary.

(1.) The coals of west Nelson, as first suggested by Professor Park,† have accumulated as marginal (probably drift) deposits.

(2.) The coal-measures belong to one system only, and present an unbroken sequence.

(3.) The more highly carbonized coals are generally the more elevated, or, more exactly, those from above which the impervious strata have been removed wholly or in part. This "stripping" permitted a relatively rapid escape of distillation-products and a relatively rapid distillation of the vegetable matter. It should be noted that Professor Park‡ has long insisted on the influence exercised by the character of the overlying measures in determining the formation of different classes of coal.

(4.) The chances of large supplies of petroleum being found in west Nelson are not good. A certain amount may occur along faults.

Art. XXXVI.—*On the Genesis of the Surface Forms and Present Drainage-systems of West Nelson.*

By J. Henderson, D.Sc., A.O.S.M.

Communicated by Professor James Park.

[*Read before the Otago Institute, 14th September, 1909.*]

The term "west Nelson" as here used includes all that part of the north-west of the South Island which lies to the west of the main divide and north of the Taramakau. This portion of New Zealand has an area of close on 8,000 square miles, and consists of a series of earth-blocks, which at one time presented a comparatively even surface, but which have suffered such a differential elevation that some of the blocks have been raised till their surfaces are 5,000 ft. or more above the surfaces of the other blocks,

* Morgan: Geol. Surv., 3rd Ann. Rep. (n.s.), pp. 9, 10. Webb: *Idem*, p. 23.
† Park: "Geology of New Zealand," 1910, p. 280 *et seq.*
‡ Park: "Mining Geology," 2nd ed., 1907, p. 32.

forming a group of block mountains analogous to those in Otago,* except that, having been subjected to the more active denudation-conditions obtaining in this portion of New Zealand, they have been more thoroughly dissected. At present only the comparative equality in height of the higher peaks indicates the ancient peneplanation.

FAULTS.

There are, then, two elements in the geography of west Nelson—the peneplains and the rift-valleys—and the limits of both of these are generally determined by powerful faults. There are two groups of normal downthrow faults, separated by the great alpine overthrust, those lying to the west of this overthrust belonging to west Nelson, and those to the east to the alpine range.

The main structural fault of west Nelson, and, indeed, of the South Island, is the great alpine overthrust† which runs from Foveaux Strait to D'Urville Island. This overthrust follows the Gregory Valley of Morgan,‡ which may be traced from Lake Kaniori to Lake Rotoiti.§ Its course has been indicated by Hector|| and Mackay.¶ On the western side of this great fault have been intruded igneous magmas, which abut at intervals against the overthrust from South Otago to Lake Rotoiti, in Nelson. On both sides of the fault occur basic and ultrabasic intrusions of later age than the granitic intrusions already mentioned. On the east side they occur from D'Urville Island to Otago, forming in part the Pounamu formation of the Geological Survey. On the west side these rocks are represented by lavas at Koiterangi and Paringa, and by dykes at many points.

The faults of the alpine range are exceedingly numerous, and tend to run either north and south or east and west.** They are often indicated by hot hepatic springs, as in valleys of the Maruia, Upper Grey, Hurunui, Trent, and Taipo Rivers. North-and-south faults occur in the Upper Taipo, Otira, Waikite, and Trent. East-and-west lines of faulting—perhaps *blätten*—are followed by the Upper Taramakau and Hurunui, the Waiheke, and Doubtful, the Marchant, Upper Grey, Maruia, and Henry Rivers. The Wairau†† fault is different from the faults of the alpine peneplain, hitherto considered: it has a more easterly trend than either the main alpine overthrust or the great faults of the Kaikouras and North Island ranges—it is, in fact, a connecting-link between these two great parallel systems of breaks.

The faults to the west of the alpine overthrust tend to run in two directions—north and south, and north-east and south-west.‡‡ The first to be considered, the Motueka fault, probably skirts the coast of Tasman Bay, running south from Separation Point to the mouth of the Motueka,

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* Park: N.Z. Geol. Surv. Bull. No. 2 (n.s.), p. 6 *et seq.*; No. 5 (n.s.), p. 6 *et seq.*; "Geology of New Zealand," 1910, p. 11.

† Mackay: Geol. Surv., No. 21, p. 20. Morgan: N.Z. Geol. Surv. Bull. No. 6 (n.s.), p. 71 *et seq.*

‡ Morgan: N.Z. Geol. Surv. Bull. No. 6 (n.s.), p. 38.

§ Haast: Geol. Explor. of West Nelson, p. 94.

|| Hector: Geol. Surv., No. 4, p. 29.

¶ Mackay: Mines Statement and Goldfields Reports, 1893, pp. 136, 174.

** *Cf.* Morgan: N.Z. Geol. Surv. Bull. No. 6 (n.s.), p. 70.

†† Mackay: Geol. Surv., No. 21, p. 19.

‡‡ Park: Geol. Surv., No. 19, p. 83. Mackay: Geol. Surv., No. 21, pp. 20, 21. Mackay: Geol. Surv., No. 12, pp. 124, 125, 127 (in this and in many following references faulting is not definitely stated, but may be inferred).

where it turns south-west and follows the flanks of the Mount Arthur Range, contorting the strata in the Graham, Baton, and Wangapeka Rivers. One branch runs south-east along the Sherry River,* and probably reaches the alpine overthrust near Lake Rotoiti. The main fault is continued into the basin of the Owen,† which river it follows to the junction of the Mangles, thence crossing to the Matakitaki. The Tutaki† fault leaves the Motueka fault at the Owen, flanks the Murchison peneplain on the west, into the head of the Tutaki, thence by the Glenroy junction along the Warbeck and Warwick Rivers to the Maruia. The Matiri‡ fault, parallel to the Motueka fault, shows itself in the Upper Wangapeka and probably the Upper Crow, follows the Upper Matiri to the Maruia junction, thence by Deepdale into Larry's Creek, and flanks the Victoria peneplain on the west, reaching the alpine overthrust near Lake Haupiri.

The Takaka fault§ follows the Takaka River for twenty miles, thence crosses the range joining the Motueka fault near the Baton. The Karamea fault‖ crosses the Mount Arthur tableland from the Takaka to the Leslie, thence into the Upper Karamea; it determines the course of the north and south branches of the Mokihinui, thence to the Buller by way of New Creek. The Mawhera fault,¶ a direct continuation, flanks the eastern base of the Paparoas, running to sea south of the Taramakau. A subsidiary parallel fault to the west determines the course of the Orikaka and Blackwater Rivers. The Inangahua fault** leaves the Karamea fault at New Creek, flanks the western base of the Brunner Range and the foothills of Victoria Range, reaching as far south as the Big Grey, where its southern continuation is overlain by Old Man gravels. The Ross fault†† is a south-west fault, flanking the western of the granite foothills from the Grey River to Ross; it manifests itself at Koiterangi and Mount Greenland.

The Aorere fault‡‡ runs along the western shores of Golden Bay and follows the Aorere, and thence by way of Brown's Creek across the Gouland Downs. The Wanganui fault runs south-west through West Wanganui Inlet, and a probable parallel fault determines the trend of the coast from Cape Farewell to Rocks Point. The Lower Buller fault§§ follows the coast-line south-west from north of the Mokihinui, and skirts the higher land from the Ngakawhau to the entrance of the Buller Gorge, thence to the coast at the mouth of Fox's River. The Mount William fault‖‖ flanks

* Mackay: Geol. Surv., No. 12, p. 130.

† Haast: Geol. Explor. of West Nelson, pp. 95, 96. Cox: Geol. Surv., No. 16, pp. 5, 6, 8. Park: Geol. Surv., No. 19, pp. 79, 82, 84.

‡ Hector: Geol. Surv., No. 4, p. 27. Cox: No. 16, p. 6. Park: No. 19, p. 80. Mackay: Geol. S.W. Nelson, pp. 11, 12, 57.

§ Park: Geol. Surv., No. 20, p. 192. Mackay: No. 21, p. 21. Bell: N.Z. Geol. Surv. Bull. No. 3 (n.s.), p. 50.

‖ Hector: Geol. Surv., No. 4, p. 27. Cox: No. 9, p. 117. Mackay: No. 21, p. 21: Mackay here ascribes the dislocation of the rock at the base of the Lyell Mountains and at New Creek to his Motueka fault. Mackay: Geol. S.W. Nelson, p. 12.

¶ Mackay: Geol. Surv., No. 8, pp. 103, 104, 105; No. 21, p. 21 (Motueka fault); Geol. S.W. Nelson, p. 58.

** Mackay: Geol. Surv., No. 15, pp. 145, 146, 147.

†† Bell: N.Z. Geol. Surv. Bull. No. 1 (n.s.), p. 81. Morgan: N.Z. Geol. Surv. Bull. No. 6 (n.s.), pp. 70, 71.

‡‡ Hector: Geol. Surv., No. 4, p. 19. Cox: No. 15, pp. 71, 72. Park: No. 20, p. 202. Bell: N.Z. Geol. Surv. Bull. No. 3 (n.s.), p. 50. Mackay: Papers and Reports, 1896, C.-11, p. 9.

§§ Mackay: Geol. Surv., No. 8, pp. 107, 109, 112; No. 21, pp. 22, 78.

‖‖ Mackay: Geol. Surv., No. 8, pp. 76, 110, 113; No. 21, p. 78; Geol. S.W. Nelson, p. 58. Webb: Geol. Surv., 2nd Ann. Rep. (n.s.), p. 26.

the granite ranges south from Mount Domett, enters the Mokihinui basin by Rough-and-Tumble Creek, thence along the Upper Ngakawhau and Waimangaroa, past Mount William, and across the Buller by way of Cascade Creek; thence it flanks the Paparoa peneplain to Point Elizabeth: a branch probably crosses the Grey between the first and second gorges.

The faults of west Nelson, as far as the writer can tell, are all distributed faults, often many chains wide.

PENEPLAINS.

The fractures of which the general course has just been indicated separate the two main elements in the geography of the area, the peneplains and areas of depression.

The most northerly elevated earth-block is that forming the Whakamarama Range. This peneplain has a north-east and south-west extension, and is bounded by the Aorere and Wanganui faults. The highest peak is 3,980 ft., and several peaks attain 3,500 ft. This block consists mainly of Palaeozoic rocks with a north and south or north-north-east and south-south-west strike.* It is skirted on the west by a belt of Tertiaries, and is overlain on its northern limb by the same rocks.†

The Pikikiruna peneplain is bounded by the Motueka and Takaka faults. The highest peak is 4,359 ft., and the average of five peaks is 3,920 ft. The slope is to the north half of this earth-block, to the north and east is of granite, the rest of Palaeozoic rocks,† the strike of which varies much from north-east and south-west to north and south.‡

The Mount Arthur peneplain is the principal one in this part of the country. From it have been carved the Mount Arthur, Douglas, Haupiri, Anatoki, and Leslie Ranges. It is limited by the Takaka and Motueka faults on the east; on the west by the Aorere fault and by a probable continuation of the Mount William fault. It is separated from the Lyell peneplain on the south by the saddle between the Baton and Karamea. This depression may be a fault-rift, or it may be a col between the truncated domes (uplifted by the laccolites beneath) of the Mount Arthur and Lyell peneplains. The Mount Arthur peneplain is traversed by the Karamea fault, which cuts off the Mount Arthur Range from the rest of the peneplain. The highest point is 6,000 ft. above sea-level, and the mean of eleven peaks is 5,110 ft. Granites appear right along the eastern and western borders of this earth-block, and in patches in the north; in fact, the Palaeozoic sediments which form the central portions rest on a vast plinth of granite.§ These sediments contain numerous dykes, and strike from north-west and south-east to north-north-east and south-south-west.||

The Lyell peneplain is determined on the east by the Motueka fault, on the west by the Mount William fault, on the north by the col before mentioned, and on the south by the Upper Buller Gorge, which the Buller has formed by cutting through the saddle between the Lyell and Victoria peneplains. The Karamea and Matiri faults traverse this peneplain. The

* Cox: Geol. Surv., No. 15, p. 66.

† Park: Geol. Surv., No. 20, p. 186 *et seq.*

‡ Cox: Geol. Surv., No. 13, p. 2. Park: No. 20, p. 228. Hochstetter's "New Zealand," p. 102.

§ Mackay: Geol. Surv., No. 12, pp. 102, 122. Cox: No. 14, pp. 43, 44; No. 15, pp. 63, 64. Park: No. 20, pp. 230, 231. Bell: N.Z. Geol. Surv. Bull. No. 3 (n.s.) p. 70 *et seq.*

|| Mackay: Geol. Surv., No. 12, pp. 125, 127, 128. Cox: No. 14, pp. 45, 49, 50, 51 Park: No. 20, pp. 210, 211, 213, &c. Bell: N.Z. Geol. Surv. Bull. No. 3 (n.s.), pp. 34, 45

highest peak is 5,750 ft., and the mean of twenty peaks is 4,800 ft. In structure the Lyell peneplain resembles the Mount Arthur peneplain, the ancient sediments, and in part also Cainozoic rocks resting on a platform of granite. Thus on the west the peneplain is edged by the granites of Mount Radiant and Mount Glasgow, and granites occur on the south and east.* The strike of the older sediments is nearly north and south.†

The Murchison peneplain is separated from the Lyell peneplain by the Motueka fault. It is determined on the west by the Tutaki fault, on the south-east by the alpine overthrust, and on the east by the Sherry fault. The highest peak is 4,629 ft., and the mean of eight peaks is 4,000 ft. This block is low on the east, due to denudation and to the overriding of the alpine peneplain. It has been very thoroughly dissected, so that only on the west do sediments which strike north and south occur.‡ To the east the granite has been cut out into isolated pyramids.

The Victoria peneplain, the remnants of other domes, is bounded by the alpine-overthrust and Matiri faults. The Matiri fault traverses its northern end, and roughly separates the Brunner and Victoria Ranges. The highest peak is 5,571 ft., and the mean of twenty peaks is 4,930 ft. Denudation has removed nearly all the sediments first uplifted by the laccolites. A strip of slate with a north-and-south strike§ borders its western flank. Patches of Cainozoic rocks occur on the west and north-east.

The Wainihinihi peneplain|| flanks the alpine divide as far north as Bell Hill. The alpine overthrust separates it from the alpine peneplain, and on the west it is determined by the Ross fault. This peneplain, which has a north-east and south-west extension, has been very thoroughly dissected by rivers flowing across it from the alpine peneplain. It now consists of a series of pyramidal peaks with an average height of, say, 4,000 ft. The sediments which formed part of its original mass occur only as narrow strips flanking the west of the peaks from Bell Hill to Ross, and striking north-north-east to north-west.¶

The Paparoa peneplain is a truncated dome the sediments of which flanked it before peneplanation; elevation and faulting are now represented by the slates at its northern and southern extremities, which strike from north-west to north-east.** It is bounded by the Mawhera and Lower Buller faults. Its highest peak is 4,250 ft., and the mean of five peaks is 4,000 ft. This peneplain is almost entirely surrounded by Cainozoic rocks derived from its own degradation.††

The alpine peneplain is of the same age as the other peneplains of the area. It stretches without break from D'Urville Island to Otago.

The wonderfully well-preserved groups of block mountains occupying Central and North Otago, first described by Professor Park,‡‡ are the

* Haast: Geol. Explor. of W. Nelson, pp. 98, 99. Mackay: Geol. S.W. Nelson, p. 66. Webb: Geol. Surv., 2nd Ann. Rep., pp. 26, 27.

† Park: Geol. Surv., No. 19, pp. 81, 82. Webb: *Loc. cit.*, p. 27.

‡ Park: *Loc. cit.*, pp. 81, 82.

§ Haast: Geol. Explor. of W. Nelson, p. 101. Mackay: Geol. Surv., No. 15, p. 123 *et seq.*

|| Bell: N.Z. Geol. Surv. Bull. No. 1 (n.s.), p. 26.

¶ Bell: *Loc. cit.*, p. 46. Morgan: *Ibid.*, No. 6 (n.s.), p. 97.

** Cox: Geol. Surv., No. 9, p. 76.

†† Mackay: Map with Geology of S.W. Nelson.

‡‡ Park: N.Z. Geol. Surv. Bull. Nos. 2 and 5 (n.s.), 1906, 1908; and "Geology of New Zealand," 1910, pp. 10, 11, 144.

remains of the Otago peneplain, which is merely the southern continuation of the alpine peneplain of Canterbury and Westland.

On the west the alpine peneplain is bounded throughout its entire extent by the great alpine overthrust. It occupies a great part of Marlborough, east Nelson, and Canterbury. Like the other peneplains, it has been subjected to differential uplift, and, on the whole, the uplift has been greater. From the head of the Taramakau to the head of the Maruia the average height of the peaks is about 6,000 ft.; from Cannibal Gorge to Lake Rotoiti the mean is well over 7,000 ft.; while north of Lake Rotoiti few of the summits overtop 5,000 ft., and going north the height sinks gradually to 2,000 ft. on D'Urville Island.

THE AREAS OF DEPRESSION.

The first of these to be considered, the Taitapu depression, is at present occupied to a great extent by Golden Bay. It is bounded on the west by the Aorere fault, and on the south by a probable fault parallel and subsidiary to the Cook Strait fault, which passes north of Cape Farewell. Two arms of this depression extend southward along the rift-valleys of the Aorere and Takaka. These two prolongations are filled with three series of deposits. The oldest of these deposits consists of conglomerates, sandstones, and limestones of probable Miocene age; the next deposit consists of gravels, and mudstones laid down when the land stood at a lower level —probable age Pleistocene; the other series of deposits are the gravels of Recent age.

The Whakatu rift-valley is bounded by the Motueka, Sherry, and alpine-overthrust faults. Its northern depressed end is occupied by Tasman and Blind Bays. The southern end is occupied by a vast deposit of gravels —the Moutere gravels—of Pleistocene age. On the south these gravels cover—in fact, completely cross at one point—the Murchison peneplain. At numerous points around the edges of the valley the Miocene coal-measures outcrop, and it seems reasonable to suppose they form the floor of the whole valley.

The Kawatiri rift-valley, separated from the Whakatu Valley by the Murchison peneplain, is bounded by the Tutaki, Matiri, and alpine-overthrust faults. It lies at a higher level than the areas of depression hitherto described, and is occupied chiefly by the Miocene rocks, the Pleistocene gravels which may at one time have covered the coal-measures having been almost entirely removed.

The Oweka depression (named from the Maori name for the plains of the Inangahua*) lies between the Victoria and Paparoa peneplains, and extends northward into the valley of the Orikaka, and perhaps into the basin of the Mokihinui. It is bounded by the Mawhera, Inangahua, and Ross faults. Like the other rift-valleys, its floor is covered with Miocene strata, which in turn are overlaid by Pleistocene (Old Man) gravels and Recent river-wash.

A long depressed strip faces the Tasman Sea, in places sinking in steps from the Paparoa, Lyell, and Mount Arthur peneplains, which bound it on the east. In this coastal strip occur the basement rocks, granite, greywacke, the Miocene coal series, Pleistocene and Recent gravels.

* Haast: Geol. Explor. of W. Nelson, p. 76.

Geological History.

A tentative account of the later geological history of west Nelson is here put forward. In Mesozoic times what is now New Zealand formed the littoral of the primary coast of the Pacific Ocean. The vast accumulation of sediment which seems to precede the formation of fold-mountains was deposited. Then a fold-movement was initiated, probably contemporaneous with the sinking of the land now occupied by the Tasman Sea. This folding ridged the land into a series of folds running north-north-east and south-south-west to north-west and south-east, or, say, on an average north and south.* Then, probably in late Mesozoic or early Cainozoic times, the alpine orogenic folding commenced, which culminated in the production of the great alpine overthrust. This crosses the older north-and-south folds obliquely, running as it does north-east and south-west parallel to the alpine folds. The pressure forced molten magmas† into the rocks along the lines of weakness. Of these lines of weakness the principal is the alpine overthrust, and granites occur just to the west of this line in west Otago and from Mount Bonar in Westland to Lake Rotoiti in Nelson. Besides the granites immediately abutting on the alpine overthrust, the intense pressure from the east forced up magmas along lines of weakness farther to the west. Thus great laccolites occur along the axes of the older north-and-south folding. In west Nelson the longer diameter of the granites of the Murchison peneplain are continued north-north-east and north to Separation Point, and the granites of Victoria peneplain trend north and south, and their northern end is very close to and perhaps continuous with the granites flanking the west of the Lyell and Mount Arthur peneplains. These north-north-east and south-south-west lines of weakness continued northward pass through Taranaki and the Auckland Peninsula, while the alpine-overthrust line passes near Taupo and White Island. It is probable that even at this period the great fracture-lines had been initiated,‡ the breaks running north and south or north-east and south-west, according as the influence of the north-and-south folding or the pressure from the south-east predominated. At already pointed out, the faults of the alpine peneplain strike nearly either north and south or east and west, while the overthrust strikes north-east and south-west. It is suggested that the north-and-south faults follow lines of weakness developed by the old north-and-south folding, while the east-and-west faults represent the breaking-back of the fissures to the line of greatest tension.

The land seems to have been above sea-level till Tertiary times, when depression permitted the inroads of the sea into the rift-valleys which had already been formed. Deposits accumulated in these rift-valleys. In ascending order, they are conglomerates, sandstones, and shales with coal-seams; then mudstones and dark strata, analogous to those at present forming on the shores of Blind and Golden Bays, West Wanganui Inlet, Otago Harbour, and, indeed, any land-locked arm of the sea silting up. Further depression permitted the formation of sandstones, calcareous sandstones, arenaceous limestones, and finally pure shelly limestones. When these last were formed the land-surface of what is now west Nelson was

* *Cf.* Morgan: N.Z. Geol. Surv. Bull., No. 6 (n.s.), p. 78. Dobson (quoted by Hochstetter, "New Zealand," p. 483) states that the strike of the beds is north-east, while the general trend of the range is north-east.

† The granites of west Nelson are not at all the same age.

‡ The numerous lodes of west Nelson occur near the great faults.

represented by a series of base-levelled islands, to the east the long line of what is now the alpine peneplain rose from a shallow sea.

Elevation now took place. In this portion of New Zealand the elevation was of the plateau-forming order, merging into the fold-movement of the Kaikouras and North Island ranges. This fold-movement was accompanied, perhaps casually, by the foundering of the northern continuation of the alpine peneplain. The elevation was accompanied in west Nelson by the intrusion of the unconsolidated ultrabasic portions of the magmas, of which the acid portions are represented by the granites that even in Miocene times had been exposed by denudation. The lavas of Koiterangi and Paringa and the dunites of the Pounamu formation belong to this period. Here also belong the protogines and hornblende granulites produced by movement along the alpine overthrust. The elevation was of a differential nature, and the alpine peneplain was elevated more than the other peneplains. Again, different parts of the alpine peneplain were differentially elevated, and the greatest elevations seem to be immediately opposite to the depressions on the west of the overthrust. Thus in Westland, south of the Wanganui, the alpine peneplain has been very greatly elevated, while the granites which probably at one time occurred here to the west of the overthrust have disappeared. Again, the alpine peneplain is relatively high between the Upper Maruia and the Wairau, and to the west of the overthrust is the Kawatiri depression. Opposed to the Whakatu rift-valley and the relatively depressed alpine peneplain is the high land of the Kaikouras.

DRAINAGE.

The elevation of late Miocene times initiated a new cycle of erosion. The streams from the base-levelled land united to form larger streams, which flowed through the rift-valleys across the newly deposited strata. Thus the Aorere was formed from streams draining the west and north-west of the Mount Arthur peneplain. The Whakamarama peneplain on elevation was tilted to the north and west, and the consequent streams flow north-west to the sea: later, the Kaituna broke through the eastern fault-scarp and captured some of this drainage for the Aorere, which, however, lost its head-waters to the Heaphy and Big Rivers.* The Takaka cut out its channel along the Takaka and Karamea faults as far as the Upper Karamea,† which was afterwards captured by the Karamea in accordance with the law of greatest slopes. The Kawatiri basin at this time drained into the Whakatu,‡ while the Oweka rift-valley was drained by a river having the head-waters of the Mokihinui as its course, and its mouth near Lake Brunner.§ Tributaries from the alpine peneplain flowed right across the intervening Victoria peneplain: such were the Ahaura, Upper Grey, and Inangahua, the volume of the latter being then increased by the present Upper Maruia. Similarly, the Taramakau flowed across the Wainihinihi peneplain.

A pause in elevation permitted the river-systems to mature and a vast accumulation of gravels to be formed. These gravels occur in the valleys of the Aorere and Takaka. The Whakatu filled its valley with the Moutere

* Cox: Geol. Surv., No. 16, p. 67.

† Mackay: Gold-deposits of N.Z., p. 11.

‡ Cox: Geol. Surv., No. 16, p. 68. Park: Trans. N.Z. Inst., vol. 37, p. 549.

§ Haast: Geol. Explor. of W. Nelson, p. 103. Marshall: Geog. of N.Z., pp. 140, 141.

gravels, which reach a height of 3,000 ft. above sea-level and overlap the Murchison peneplain right to the Kawatiri basin. The Oweka Valley was filled by the gravels of the Old Man Bottom, which as they were pushed farther and farther south overlaid the beds known as the Blue Bottom. These are practically contemporaneous with the Old Man Bottom beds, and were laid down in a shallow bay, to be ultimately covered by the advancing delta of the Oweka and other lesser streams from the alpine peneplain.

Further elevation now took place, and the present cycle of erosion commenced. The peneplains, lifted more rapidly than the rift-valleys, were now sufficiently high to allow vast snowfields and glaciers to form. They were not at that time so thoroughly dissected as at present, and the surface of high land was much greater than now. The Mount Arthur, Lyell, Victoria, and Paparoa peneplains all testify to the former existence of glaciers, and the alpine peneplain shows traces of a much more extensive glaciation than now obtaining. This elevation brought about many changes in the river-systems. The Wairau, eating back along the great Wairau fault, captured the head of the Motueka.* The Oweka had formed a coastal plain, and its mouth had been forced to the north by the prevailing northerly drift. When elevation took place it was handicapped in cutting back by the hard Miocene sandstone immediately underlying the alluvium of its lower course Moreover, the eroding-power near its mouth was greatly lessened by the deposition of the great bulk of the sediment in its sluggish middle course. The Mokihinui and Buller, small consequent streams, broke into and captured the upper portion of the Oweka. The Mokihinui had only the rock-bound source of the Oweka, but the Buller reached the unconsolidated Old Man gravels, and carved its way south, capturing the Inangahua,† which had already been beheaded by the Upper Grey. The stream which cut the Upper Buller Gorge had now a greatly augmented eroding-power, and captured the drainage of the Kawatiri basin, the outlet to the Wairau being blocked by the great glaciers which formed Lakes Rotoroa and Rotoiti. The conquest of this basin was contemplated when the head of the Maruia was transferred from the Upper Grey.‡ This must have taken place almost within historic times.

At one time, also, the streams forming the Grey formed a river flowing to the east of its present course. A range of Old Man Bottom hills lies between this old course and the present course of the Grey.

Summary.

(1.) West Nelson consists of a series of earth-blocks differentially elevated.

(2.) The fault-lines separating the blocks were probably established at the time of the intrusion of the granites, consequent on the orogenic movement which formed the alpine chain.

(3.) The first cycle of erosion, which was very complete, produced the coal series and base-levelled the elevated earth-blocks. The radial drainage obtaining on the western portion of the Mount Arthur peneplain and on the Pikikiruna, Lyell, and Paparoa penplains has probably been evolved from this ancient drainage.

* Haast: Geol. Explor. of W. Nelson, pp. 3, 90, 91.
† Haast: *Loc. cit.*, p. 103. Marshall: Geog. of N.Z., pp. 140, 141.
‡ Mackay: Geol. of S.W. Nelson, p. 43. Mines Statement, 1893, p. 175.

(4.) The second cycle of erosion, though less complete than the first, produced the fluvio-glacial Moutere drifts and the Old Man Bottom gravels, and was initiated by the forcing-up of the peneplains and the consequent reopening of the fractures. The Whakamarama peneplain was tilted to the north-west and the Victoria peneplain to the west, and to this is due their present drainage. The higher elevation of the alpine peneplain caused its western drainage to cross the Wainihinihi, Victoria, and Murchison peneplains where these abut against the alpine peneplain. The drainage of the lower country, which dates back to this time, has been most profoundly influenced by the great fracture-lines, especially in the alpine peneplain.

(5.) The third, or present, cycle of erosion is very incomplete. Further movement took place along the fracture-lines, and certain changes in the drainage.

ART. XXXVII.—*The Mount Arrowsmith District: a Study in Physiography and Plant Ecology.*

By R. SPEIGHT, M.A., M.Sc., F.G.S.; L. COCKAYNE, Ph.D., F.L.S.; and R. M. LAING, M.A., B.Sc.

Plates III–VII.

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PART I.—PHYSIOGRAPHY.

By R. SPEIGHT, M.A., M.Sc., F.G.S.

[Read before the Philosophical Institute of Canterbury, 1st June, 1910.]

1. INTRODUCTORY.

THIS paper deals with the physiography of a part of Canterbury which is little known even now. Although reference is made to its general physical features. those which depend on glaciation, both present and past, receive most attention. In presenting this account I have to acknowledge my indebtedness to Sir Julius von Haast on points so numerous that it is impossible to mention them in detail. I therefore take this opportunity to make a general acknowledgement of my debt, and also to express, as one who has followed in his footsteps, even if a long way after, my appreciation of the work which he did in this locality nearly fifty years ago. Considering that physiographical geology was almost unknown as such at the time when he visited the head-waters of the rivers referred to later, it is most surprising to find what a wonderful grasp he had of the principles which underlie that phase of geological study, and, even if he did not know processes and results by the names which are applied nowadays, he certainly had a proper appreciation of their importance, and clearly recognized their operation in nature.

I must also acknowledge my indebtedness in a minor degree to Captain Hutton and to S. H. Cox for their descriptions of portions of this area.

My own conclusions are based on observations made during four separate journeys to various parts of the district.

2. MOUNTAIN SYSTEMS.

(*a*.) *Topography.*

(See map, p. 318.)

The district dealt with in this paper lies at the head of the Ashburton and Rakaia Rivers, and forms part of the eastern slopes of the main range of the Southern Alps, in lat. 43° 20′ south approximately. In this part of the range its average direction is north-east to south-west, but owing to extensive erosion by rivers and glaciers the valleys on either side dovetail into one another in a most remarkable manner, so that the actual crest is a very irregular line. The principal peaks, taking them in order from Whitcombe Pass to the head of the Rangitata River, are the following: Louper Peak (8,165 ft.), Mount Whitcombe (8,656 ft.), Blair Peak (8,185 ft.), Malcolm Peak (8,236 ft.), and Mount Tyndall (8,282 ft.). Running east from the main range, and forming the main divide between the upper valleys of the Rangitata and the Rakaia, is an elevated ridge connecting the Arrowsmith Range with the central mountain system. This ridge is everywhere over 5,000 ft. in height, and has several prominent peaks on it, notably Mount Goethe (over 6,000 ft.) and Mount Murray (7,065 ft.). The Arrowsmith Range stretches in a north-east to south-west direction, generally parallel to the Southern Alps, and rises to a height of 9,171 ft. in Mount Arrowsmith itself, with numerous minor points about 8,000 ft. Mount Arrowsmith is thus higher than any peak in the vicinity, and, indeed, is higher than any peak on the main divide behind it with the exception of those in the Mount Cook group. The same peculiarity in the

position of the highest peaks with regard to the mountain axis of the South Island is to be observed further south, where Mount d'Archiac (9,279 ft.) in the Two Thumb Range, Malte Brun in the Maltebrun Range, and Mount Cook itself lie to the east of the main watershed, and excel in elevation the neighbouring peaks on it. The crest of the range also lies far to the east of the structural or tectonic axis of the Island, which no doubt follows up through the schistose belt between the sea and the present main range about twenty miles from the west coast. This suggests that the present configuration has been the result of excessive erosion acting for a long

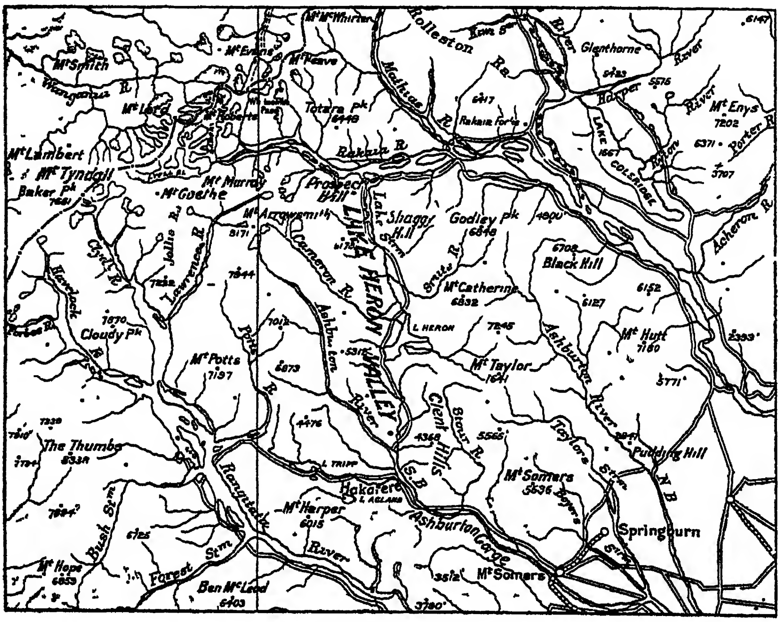

Fig. 1.—Map of Mount Arrowsmith District.

period of time on the western wing of the geanticline of which the range has been built, far more profoundly than it has acted on the eastern wing.

(b.) *Relation to Rainfall and Conditions of Erosion.*

The mountains in this locality lie right across the direction of the prevailing westerly winds of this latitude, and the bulk of the moisture is intercepted on their western slopes. The conditions are exactly the same as these further north at Otira, which, according to the records of the meteorological station recently established, has a yearly rainfall of a little over 200 in., while at Bealey, about twelve miles away in a straight line, it is only 100 in. Although no statistics are available for the Rakaia region, the effect is clearly visible in the character of the plant covering, which changes from the rain forest of Westland to the markedly xerophytic tussock steppe of the region to the east of Mount Arrowsmith. Intermediately there is the totara forest of the Upper Rakaia, which has followed the rain just across the main divide from the montane rain forest containing totara on the higher hill country of Westland.

These different conditions of rainfall have probably lasted for a very long time, and their effect is evidenced by the lower elevations to the west, where the subaerial denudation has been excessive, owing to the heavy rains causing frequent floods and the great amount of snow forming large and powerful glaciers. There is evidence from other parts of the Alps that the dominant western erosion has resulted in the capture by the western streams of the upper tributaries of some of the rivers of the eastern watershed. It is only in some such way that the formation of Arthur's Pass can be explained. This action is likely to continue when the marked difference in the height of the floors of the eastern and western valleys is considered—for example, the floor of the Bealey Valley near the tunnel-entrance is at an altitude of 2,435 ft., while the western end, at Otira, five miles and a quarter distant, is only 1,583 ft.—that is, it is 852 ft. lower. The same is generally true for the other valleys of that part of the Southern Alps, a feature well brought out by Mr. Edward Dobson's original surveys for a road across the range. This remarkable physical peculiarity can be most easily explained by the greater efficiency of eroding agents on the western side of the range. The heads of the valleys have been sapped back by glaciers, and the valleys have been deepened by ice and water action so that they have been able to encroach on their eastern neighbours; and the marked overlapping of adjacent streams on either side of the crest of the range intensifies this effect when capture of even one small tributary has taken place. The more rapid erosion on the west will lower the range progressively from that direction, so that the eastern region will become of relatively higher relief, and in future geological time Mount Hutt and Mount Torlesse, on the eastern border of the mountainous country, will, if similar meteorological conditions continue, become its highest elevations.

(c.) *Present Form of Mountain Region—a Dissected Peneplain.*

The rocks of which the area is composed consist of greywackes, slates, and mudstones of Lower Mesozoic age, which have been folded subsequently by mountain-building movements into folds whose general axes run in a N.N.E.–S.S.W. direction. Local variations appear to be frequent, so that at times the direction is almost E.–W., and again become N.W.–S.E. This variation is apparently due to change in the direction of the thrusts by which the area was folded. The date of the folding is probably Upper Jurassic, but it may have been Upper Cretaceous. A feature of the mountainous region which has thus been produced is the approximately uniform height of the great majority of peaks. A very large number of these are between 6,800 ft. and 8,200 ft. in height, with very few above or below these limits except in the Mount Cook region. This suggests that the whole area has been reduced to a level platform either by marine denudation or, more probably, has been base-levelled by a former stream system, and a few peaks, like Mount Arrowsmith, which dominate the rest are the residual elevations on the peneplain. The higher mountains which no doubt once existed further west, and have been removed by erosive agents, would represent the higher mountains on this peneplain. It is possible, however, that the present prominent elevations are the remains of an old divide which existed on it, and from which streams once flowed east and west.

In advancing this theory for the present form of the mountain region of Canterbury, I am quite aware that this is contrary to the generally

accepted opinion that *in their present form* the Southern Alps are a mountain-range of the alpine type. They were undoubtedly at one time such a range, though one in which the folding was not acute, being somewhat of the nature of a series of isoclinals; but they have been base-levelled subsequently, and then raised and partially dissected. Dissection has not reached a moderately advanced stage, and a residual divide is still in existence. This is crossed by numerous passes, the lowest of which is Haast's Pass (1,716 ft. high). Such low passes are extremely unlikely to occur in a range of the alpine type unless it has suffered denudation for a long period of time. In this connection compare the Southern Alps with the European Alps, the Himalayas, or the Andes. The Canterbury peneplain formed from the original range of the alpine type was no doubt continuous with that of Otago, which, according to Professor Park* and Dr. Marshall,† has been traced with certainty as far north as the Waitaki River, with a general ascending slope from south to north. It is extremely unlikely that it broke off suddenly at the northerly boundary of the province, and it must have continued further north towards Mount Cook and the head of the Godley River. From an area of high land in that neighbourhood, or from a ridge continuing north and south from it, the present principal lines of drainage proceeded outward, and this may explain the remarkable orientation of the valleys of the Canterbury rivers noted by E. Dobson, who pointed out that the main valleys all appear to radiate from a point in the Tasman Sea about twenty miles west of Hokitika. McKay has suggested that the arrangement is due to a series of radiating faults, the lines of which are usually followed by the valleys. Of this there is not the slightest direct evidence available at present, the suggested explanation not being founded on observation, but is probably in sympathy with a somewhat mistaken tendency at the present to attribute a large proportion of landscape forms to crustal movements without positive evidence of these movements being brought forward. In this case it seems more reasonable to attribute the undoubted arrangement of the valleys to the shape of the original land-surface on which the drainage was established.

The peneplain explanation of the uniformity of the mountain-tops apparently fits the case best, although there is one consideration which must not be lost sight of—viz., the tendency of all mountain-summits in an area subject to similar conditions to approximate to a general even height. The dominant erosive agent on the mountain-slopes of this region is frost. Under the influence of its powerful action they are covered with immense quantities of moving *débris* which has been riven from the solid rocks. The pointed masses which form the highest peaks are just those which respond most readily to it. Owing to the more rapid weathering of the highest elevations they are gradually reduced to the level of the lower ones, and when the rocky eminences which crown them are destroyed the summits take on a more or less dome-shaped form owing to the accumulation of vast amounts of *débris*, which is formed faster than it can be removed by transporting agents. Although these are very active on the flanks of the mountains, they are somewhat sluggish on the tops, and become more and more so as weathering proceeds. This coating of *débris* acts as a protection, retards degradation of the mountains which have had

* N.Z. Geol. Surv. Bull. No. 5 (n.s.)—Cromwell Subdivision.
† "Geography of New Zealand."

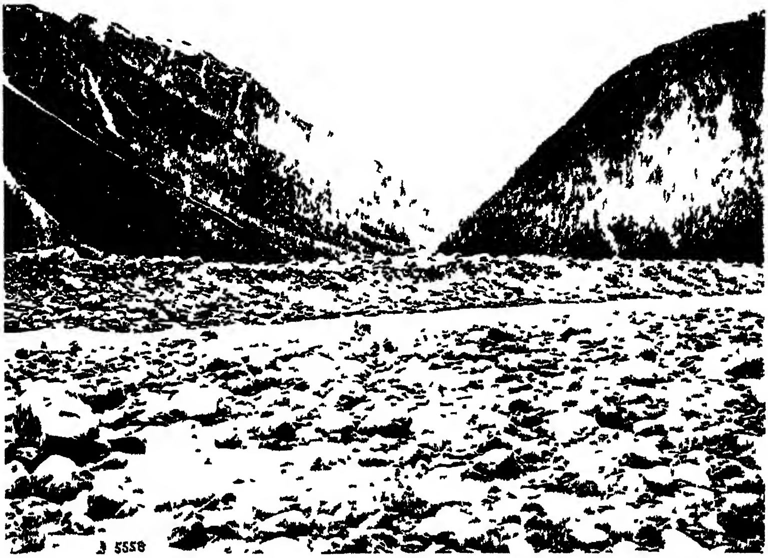

FIG 1—RAKAIA RIVER BED WITH WHITCOMBE PASS IN THE DISTANCE

FIG 2—LAKE HERON, LOOKING NORTH, SHOWING WAVE FORMED SPIT

Face p. 290]

FIG. 1.—LYELL GLACIER, FROM MEIN'S KNOB.
Mount Goethe on the left, Mount Tyndall (Haast) in the middle distance, and Malcolm Peak just showing on the right.

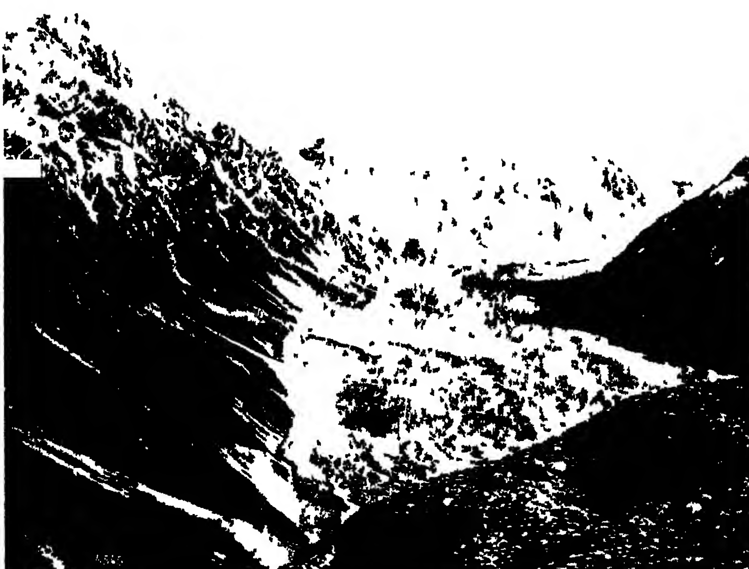

FIG. 2.—RAMSAY GLACIER, FROM MEIN'S KNOB.
Mount Ramsay on the left, Mount Whitcombe in the distance.

their prominent peaks removed, and thus promotes the gradual approximation in height. This action becomes increasingly effective as the hills become lower.

This phenomenon is noticed in all denuded mountain regions, but it is also in evidence in Canterbury, where the results of denudation have not reached such an advanced stage. If the old surface of the Canterbury plateau had been a peneplain, a generally uniform height of the principal elevations would follow, because those which stood out on it above the average level would be rapidly reduced to the mean height by the processes described above.

This rough plateau or peneplain has passed through a second cycle of erosion, and the drainage established on it appears to have reached a mature stage at the present time.

3. DRAINAGE SYSTEMS.

(a.) *Relation to the Structure of the Country.*

Mount Arrowsmith is at present the most strongly marked physical feature of the Upper Rakaia and Ashburton district. Its great mass dominates the whole area. From its south-eastern face flow the main Ashburton River, and the Cameron River, an important tributary of the Rakaia: at the back of it rises the Lawrence; while it is flanked on the north by the valley of the Rakaia, to which it contributes numerous small streams. The mountain is therefore the meeting-place of the drainage-basins of the three important rivers of central Canterbury—the Rakaia, Ashburton, and Rangitata. It must not be assumed that this has always been the case, as the directions of the river-valleys were determined at a somewhat remote date by considerations quite independent of the present surface configuration.

Its first lines seem to have been across the strike of the beds, and this accounts for the general parallelism of the course of the main rivers both inside and immediately outside the area under consideration. The principal valleys—viz., those of the Rangitata, the Ashburton, and the Rakaia—are controlled by this factor. The secondary drainage established itself in the direction of the strike, but modifications ensued as the primary streams cut deep down into the beds of the area, a characteristic modification being that the lateral valleys trend slightly down-stream, and thus cut across the strike at a small angle.

The ternary lines of drainage appear to have reverted to the primary direction, and are seen in the Upper Ashburton and the Cameron River, but the disturbing effects of glaciation have been so marked that it is unsafe to come to any definite conclusion in the matter. Even now, however, the presence of weak beds dipping at high angles undoubtedly promotes the formation of small tributary streams and of low saddles along the strike.

This arrangement of the stream system I have attributed solely to the normal development of drainage in a region composed of folded rocks where the direction of strike is fairly constant. I am quite aware that it is also possible to attribute the arrangement to lines of faulting; but until these faults can be proved on stronger evidence than the occurrence of crushed and shattered bands of rock associated with steep slopes in an area where all the rocks are more or less crushed owing to folding while the mountains were being formed, I cannot accept the theory as sound, although subsequent more detailed work may show it to be so

(b.) *The Rakaia Valley.*

The largest river of the district is the Rakaia, which takes its origin in the Lyell and Ramsay Glaciers, on the eastern side of the main divide, and runs first easterly for twenty miles and then turns south-east. It receives on its north bank numerous streams which rise in small glaciers on the main range and run in a southerly direction in parallel valleys till they meet the Rakaia. Further down, beyond the limits of the area under consideration, it receives two important branches—the Mathias and the Wilberforce. On the south bank several fair-sized streams rise in glaciers on the slopes of Mount Murray, but the main tributary is the Lake Stream. This is formed from the overflow waters of Lake Heron—hence its name—but its chief supply comes from the Cameron River. This rises in the Cameron Glacier, on the south-east face of Mount Arrowsmith, runs in a south-easterly direction for about twelve miles, and forms an extensive fan on the north-west side of the lake. At this part of its course it changes its regular channel frequently, running into the lake at times, but at present it joins the Lake Stream about two miles below its outlet from the lake. This body of water receives several streams on its eastern side, the largest being the Swin. The Lake Stream runs between north and north-east and has a very slight fall for several miles, but then it becomes swifter and makes a descent of 200 ft. before joining the Rakaia.

The Rakaia River and most of its tributaries are overcharged with detritus, and have filled up to a fairly uniform surface the floor of the glacial trough through which they run (Plate III, fig. 1). The width of the flood-plane is about two miles, and on this the river forms many diverging and anastomozing branches, in the way so characteristic of streams laden with waste. In winter it is frequently dry, owing to the freezing of the water at its sources; but in spring and summer it becomes a large river, and often impossible to cross on horseback, although the splitting-up into different streams renders it somewhat more easy to negotiate. Near the head the valley narrows somewhat, and there the river runs in a solid body of water capable of rolling down stones a ton in weight. In this part of its course no terraces are formed except those of temporary nature, but these last long enough at times to allow of their being covered with grass and scrub; still, they are liable to rapid destruction if the river in the course of its wanderings impinges for long against their unconsolidated edges (Plate III, fig. 1).

(c.) *The Lake Heron Valley: its Features and Origin.*

(See map, p. 318.)

The valley through which the Lake Stream runs is a very striking physical feature of the district. It is continued in a south-easterly direction for nearly thirty miles, and extends across the Ashburton River as far as the Rangitata. It intersects these streams nearly at right angles, and bears little relation to the present principal lines of drainage. It severs the eastern mountainous district of middle Canterbury from the main range of the Southern Alps, and well merits some distinctive name. Haast called a part of it the Upper Ashburton Plains; but this name will hardly apply to the whole extended valley. I shall refer to it in this paper as the Lake Heron Valley, as that name has been used repeatedly by the recent Commission which examined the Canterbury runs for the purpose of closer settlement. At the upper end of the valley, about five miles from the Rakaia,

it is partially blocked by Shaggy Hill, the remains of a ridge which in all probability formed part of the original divide, but which has been cut through by glacier and stream action. The floor of the valley is here about a third of a mile in width, but it immediately widens out with a broad flat section which reaches a maximum of about six miles in the neighbourhood of Lake Heron. About five miles further on it contracts somewhat, but is still four miles in width, and continues so till it reaches Hakatere Station, at the upper end of the Ashburton Gorge. Immense morainic accumulations are found here covering the whole floor and extending up a tributary valley coming in from the north-west and the direction of the Upper Rangitata, which now contains no stream at all commensurate with its size, but which was an outlet for the excess of ice in the Upper Rangitata basin. It is probable that this valley marks the original course of the Potts River before it was deflected through a low saddle which was cut down on its western side by an overflow from the Rangitata Glacier, an effect which was intensified by the overdeepening of the bed of the Rangitata itself by its own powerful ice-stream. From the junction of this tributary with the Lake Heron Valley an extension of the latter goes towards the Lower Rangitata through the Pudding Stone Valley, which is now deserted by any stream commensurate with its great width and length. From this brief description of the Lake Heron Valley it will be readily inferred that the original drainage-lines are quite distinct from those existing now.

The principal stream belonging now to this valley is the South Ashburton, which runs across it and not down it. This river rises in the Ashburton Glacier, on the south-east side of Mount Arrowsmith, and flows in a characteristically ice-eroded valley for some distance, and then passes, by means of an extremely narrow and almost impassable gorge, through elevated down country till it reaches the Lake Heron Valley. It crosses this in a wide river-bed without any distinct banks and with all the features of an aggrading stream, and afterwards penetrates the outer range of mountains by a somewhat open gorge, and emerges on to the plains near the Mount Somers Railway-station. It is joined on the northern side, about half-way through the gorge, by the Stour, the upper part of whose basin was once invaded by the ice-sheet from the great inland valley across a well-defined saddle near the Clent Hills Station. The North Ashburton does not belong to the area, as it has not cut through the outer range into the Lake Heron basin; its upper valley probably escaped the modifying influence of ice experienced by the southern branch of the river.

It seems fairly certain that in pre-glacier times the arrangement of the drainage-lines was as follows: First, a small stream joined the Rakaia where the present Lake Stream comes in. This had no great size, being only about five or six miles in length. Then the present Cameron and all the drainage of the Lake Heron basin flowed down towards Hakatere, and also received the Ashburton and the stream that came from the direction of the present Potts River, the combined streams reaching the Rangitata through the Pudding Stone Valley. The lower Ashburton Gorge was not then cut completely through, and the river rose in the hills near Mount Possession. It is certain that the formation of this gorge is of later date than the formation of the Pudding Stone Valley, and it was no doubt opened out during the glacier maximum by the overflow of ice across a low saddle, which was then lowered by its erosive action and now forms the

course of the river. These remarkable alterations are certainly due to interference arising from the glaciers when at their maximum or when declining, and how this arose will be mentioned later.

4. Lakes.

Numerous small lakes and ponds lie in the hollows formed by the morainic accumulations between the Potts River and Hakatere. The two largest of these are Lake Ackland (locally known as Lake Emma), at the head of the Pudding Stone Valley, and Lake Tripp (known as Clearwater), which lies near the Potts River. The latter is about two miles in length by about one in breadth. There is a smaller one, called Lake Howard, situated between the two. All of these lakes drain to the Ashburton. To the north of the Ashburton River, near Hakatere Station, are two shallow ponds known as the Maori Lakes, whose water is held back by a barrier of detritus deposited by the aggrading Ashburton River as it crosses the great transverse Lake Heron Valley.

(*a*.) *Lake Heron: its General Features: with Special Reference to the Spits now forming on its Shores and to the Action of Shore Ice.*

(Plate III, fig. 2.)

The largest body of water in the district, and the highest lake in Canterbury, is Lake Heron, which is at an elevation of 2,267 ft. above sea-level, and is situated on the very highest portion of the floor of the transverse valley. It has a most remarkable shape, as it almost encircles an isolated conical hill called the Sugarloaf, which rises to a height of 4,054 ft. The western part of the lake has a length from north to south of about five miles, and the southern portion a length from east to west of about four miles. Its actual breadth varies from about two miles down to very small dimensions where its two encircling arms stretch as narrow creeks behind the Sugarloaf on its north and east. The largest expanse of open water is near the south end. It is rather a shallow lake, but deep alongside the central hill, which carries down its precipitous slopes far below water-level. The shores are fringed in many places with marsh, and are usually without marked features; but my attention has been drawn to two shingle spits which are found near the south-western corner of the lake (Plate III, fig. 2). These spits are evidently the result of wave-action, without the interference of currents, usually considered to be the principal cause of the formation of such features. In this case they are so placed that it seems impossible that currents can have any part in their formation. They occur in a small lake at the end opposite to its outlet, and right at its very extremity. The most powerful wind on the lake is the north-wester, which sweeps down it from the direction of the Rakaia, and sometimes raises waves of such a size as to threaten danger to an ordinary boat. These seem to be the prime factor in the formation of the spits. Starting from a small projection of the shore, the larger spit stretches across a small bay for about 100 yards, and includes a patch of water as in a natural breakwater. The smaller spit is formed under somewhat similar conditions. When the waves are seen coming down the lake they move faster in the deeper water off shore, and gradually swing round where they meet the friction of the shelving bottom. The swing is prolonged till on breaking they are parallel to the margin of the spit; in other words, the edge of the spit is the tangent to the front of each wave as it breaks. There must, therefore, be some intimate

mathematical relation between the form of the spit and the circumstances determining the wave-motion in the lake, and an examination of the spit as they occur strongly suggests that their shape is a well-defined geometrical curve. In the initial stages of the formation of the spits it is probable that they are largely built up by a feeble shore-current due to wave-action, but directly a small spit is formed the waves would be almost entirely responsible for its prolongation. Both of these spits end in a rounded nose, whose position is determined by the amount of retardation of the wave in the shallow water. The wave will tend to swing round completely, so that it actually reverses its direction, and this will maintain a blunt-nosed spit in a fixed position as long as the conditions of the bottom of the lake in the vicinity are the same. If the floor of the lake keeps on shallowing off the spit so that it makes the depth of the lake more uniform, then the wave will not swing so quickly, and the spit will thus be lengthened (see fig. 2). The peculiarity of these spits can thus be put down absolutely to wave-action, in contradistinction to those formed on the sea-coast, which are attributed largely to littoral currents. It is evident, however, that wave-action alone can form spits, and this must be a contributory cause in a large proportion of marine spits.

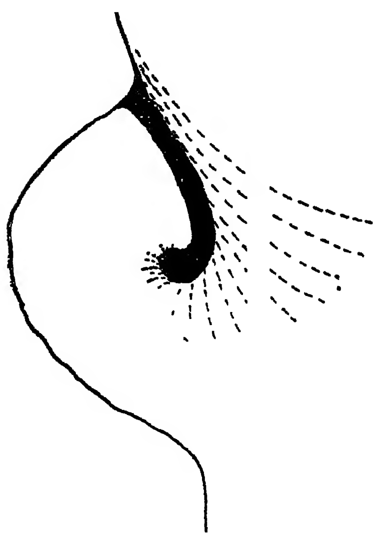

FIG. 2.—SHOWING RELATION OF WAVES TO FORM OF SPIT.

Hooked spits in lakes are specially referred to by G. K. Gilbert in his paper on the "Topographic Features of Lake-shores" (5th Annual Report, United States Geological Survey), but he ascribes them principally to the action of the littoral currents; in Lake Heron, however, these appear to play an insignificant part in their formation.

Lake Heron is at such an elevation above the sea that every winter it is heavily coated with ice. In ordinary seasons there is a covering of as much as 9 in. in thickness, a remarkable feature for such a large lake in an insular climate like ours in a latitude of only 43° S. The shores exhibit traces of the action of ice in the ridges of gravel which are pushed up by it as it expands after contraction in cold weather. Ice contracts as the temperature is lowered, and in doing so draws away from the shore, leaving a narrow lane of open water; this freezes immediately, and when the temperature rises the ice expands again and is forced up the beach. Ridges formed in this way occur on Lake Heron, as well as on the smaller lakes Tripp and Acland. The stones composing the beaches are rounded on their edges and corners by the movement of the ice, and especially so when the ice breaks up in spring before an early north-wester. The floes are then piled in heaps on the exposed shore of the lake, and the wind keeps on driving others forward, which occasionally shoot up on the inclined planes formed by the masses underneath, so that they are carried as much as a chain from the edge of the lake, scoring the ground and ploughing it into

furrows. This is especially well seen on the south shore of Lake Heron, where the full force of the northerly wind is felt and the beach is shelving and low.

5. Present Glaciers.

The existing glaciers of the area are divided into two groups—(1) those coming from Mount Arrowsmith and its immediate neighbouring heights; (2) those which belong to the main Rakaia Valley. The principal glaciers of the first group are those at the head of the Cameron and Ashburton Rivers. Several other small ones occur, notably those at the head of the Lawrence, on the western flanks of Mount Arrowsmith.

(*a*.) *Cameron and Ashburton Glaciers.*

The former glacier occupies about two miles of the upper part of the Cameron Valley. It is a small glacier of the first order, and is fed from tributaries coming from the south-eastern slopes of Mount Arrowsmith and its extension to the north. The lower part is covered with *débris*, and shows undoubted signs of recent retreat. At the present time it is almost impossible to tell the actual position of the terminal face, owing to its extreme thinness and the mantle of *débris* which passes insensibly from actual moraine to the apron of detritus before the glacier. This retreat is also evidenced by the presence of old lateral moraines lying parallel to the valley-sides far above the present level of the ice, and extending down the valley for some distance beyond the present termination. There is also there a well-marked terminal moraine about half a mile from the present face. At various positions, besides, down the valley are old terminals passing into laterals, and partially blocking the stream in several places, which marked in former times undoubted halting-stages in the retreat of the ice.

A special feature of the valley is the wide basin which forms its head, a basin evidently expanded by the sapping-back of the containing-walls in all directions by the ice which partially filled it. This case certainly suggests that corrie glaciers and glaciers which are closely related to them in size have under some conditions the power of widening their upper reaches at a faster rate than the streams which issue from them can widen that part of the valley where they flow. There is no suggestion furnished by this locality that such glaciers act as protecting agents.

The Ashburton Glacier lies to the west of the Cameron in a parallel valley, and exhibits features very similar to those of its neighbour. It is not as large as the Cameron, and hardly reaches the floor of the valley before it melts; but it is very beautiful, and shows striking crevasses and ice-pinnacles, and a fine ice-fall at its head, depending from the slopes of Arrowsmith. All down the valley in its front are the remnants of old lateral and terminal moraines in positions where they have escaped destruction by the river, and marking halting-stages in the general retreat of the ice. Immediately in front of the present face lies an immense accumulation of angular *débris* belonging to a former period, and there is evidence that the glacier has been dwindling within very recent times, though, judging from the present form of the ice-face and also from the fact that in one or two places it is crowding on to the old moraine, a temporary advance is now taking place.

The valley through which the Ashburton River flows is at first broad and flat-bottomed, but about twelve miles from its commencement it suddenly contracts, and the river passes through a deep, narrow gorge, of

recent origin, cut for about three miles through a solid rock barrier, the height of the lip above the floor of the basin on its up-stream side being over 200 ft. It is extremely likely that a lake once occupied this basin, which has been drained by the river cutting down its bed through the solid obstruction. It seems impossible to explain the peculiar relation of basin and barrier on any other assumption than that large valley glaciers have under certain circumstances great powers of basal excavation. No locality that I am acquainted with shows this better.

Immediately outside this ice-eroded basin the moderately elevated country has been dissected and the drainage-directions changed, largely as the result of glacier erosion; but I have not examined the country in sufficient detail to speak definitely on the matter, though I feel certain that it will furnish very interesting material bearing on the much-discussed question of the efficiency of glaciers as erosive agents.

(b.) *Rakaia Glaciers.*

The glaciers of the main Rakaia basin are (1) those on the flank of Mount Murray, (2) those at the head of the river, and (3) those on the north side in the system of valleys which rise in the main divide and run towards the south-west.

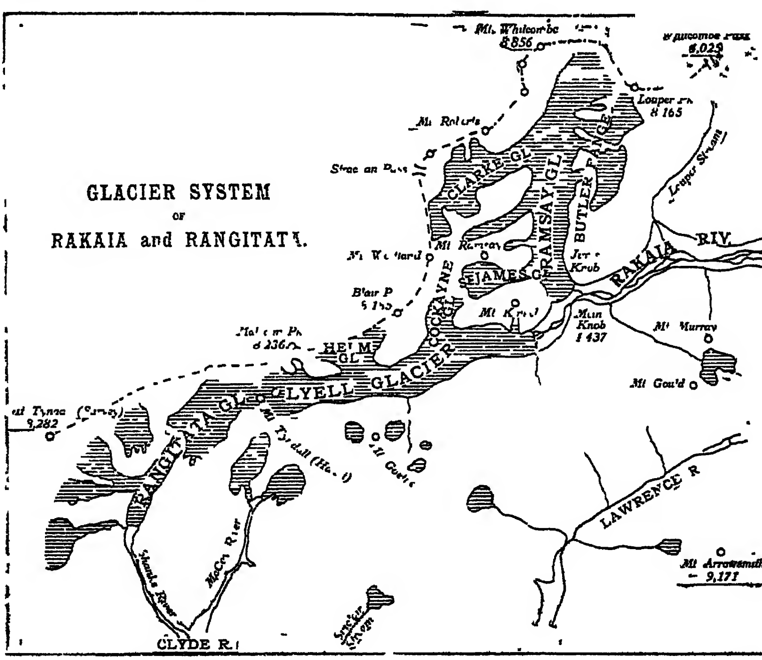

FIG. 3.—MAP OF RAKAIA GLACIERS.

On the north side of Mount Murray there are small cliff glaciers heading a stream known as the Little Washbourne, which joins the Rakaia about five miles above the outlet of the Lake Stream. Another glacier, of slightly larger size, heads a ravine on the north-west of Mount Gould, and almost

exactly opposite Whitcombe Pass. But by far the most important are the glaciers at the actual head of the Rakaia, from which the river derives a great part of its water. The furthest west of these is the Lyell Glacier.

(i.) Lyell Glacier.

(See fig. 3, and Plate IV, fig. 1.)

The Lyell Glacier was discovered by Dr. von Haast in the year 1862. He saw it from Mein's Knob, but did not actually visit it, although he must have sent on some one to take an aneroid reading of the height of the terminal face. Mr. G. J. Roberts, the late Chief Surveyor for Westland, crossed the end of it when he made his survey of the Ramsay Glacier and its neighbourhood, but he does not seem to have done more. It is thus an unknown glacier, although within a reasonable distance of settled parts of Canterbury. The present writer, with two students, made an exploration of it in December last, and the following facts about it are the result of observations made on that occasion.

The Lyell Glacier extends from Mount Tyndall* in an easterly direction for nearly five miles till it reaches to within a mile and a half of Mein's Knob, the bluff which fronts the Ramsay Glacier on the south side of the Rakaia River. It is bounded on the south by Mount Goethe, and on the north by the main range of the Southern Alps, and then by a spur from that range stretching in an easterly direction towards Mount Kinkel. The floor of the valley is a little over a half a mile wide on the average ; it is wider than lower down, immediately between Mount Kinkel and Mein's Knob, where the valley takes a turn to the north towards the Ramsay Glacier. In former times the Lyell Glacier overrode the end of the spur where Mein's Knob now is, and truncated it partially, leaving the knob with the characteristic shape produced by this mode of glacier erosion. Jim's Knob, on the opposite side of the river, has been formed in the same way by the Ramsay Glacier. The river which issues from the present Lyell Glacier may well be called the Lyell River, the name "Rakaia" being given to the stream formed by the junction of the Lyell with the twin stream from the Ramsay, the present confluence being between Mein's Knob and Jim's Knob. The two streams from the Ramsay and the Lyell appear to be of about equal size.

The Lyell River issued at the time of our visit from near the north side of the terminal face. A large body of water came from an ice-cave near the middle, ran by a tunnel under the ice in a northerly direction, and added considerably to the volume of the main stream. Behind the ice-cave the cliffs rose to a height of 60 ft. A small creek coming from the east side of Mount Goethe enters the valley on its south side immediately below the end of the glacier. This marks roughly the present position of the face. The floor of the valley is kept fairly clear of morainic accumulations by the transporting action of the powerful stream issuing from the glacier. About a half a mile down a high mound still remains which belonged to a former lateral moraine ; but even this shows signs of being rapidly removed by the river. It is hard to tell from the present form of the terminal face whether the glacier is retreating at the present time, but the southern side shows signs of a collapse, which suggests that this is the case.

* This is not Mount Tyndall of the Westland survey, but the peak called so by Haast when exploring the Upper Rakaia Valley. The name has been retained in this paper, although it must certainly be replaced by another at an early date.

The terminal face is easily climbed by means of the moraines, and for some distance up—nearly half a mile—the whole surface of the ice is completely buried; after that the lines of moraines from glaciers are separate and better defined.

Mount Goethe, which flanks the glacier on the southern side, is a mountain of considerable bulk, but without a distinct peak forming its summit. Small perched glaciers occur on it, particularly on the side of a small valley joining the main one about three-quarters of a mile from the end of the glacier; but no glacier joins the main stream at the valley-level, except a small one near the head. Although Mount Goethe is high enough to nourish fair-sized glaciers, the high range to the west precipitates the vapour and the wind reaches the other side of the Lyell Valley in a comparatively dry condition. The heavy precipitation causes the north side of the valley, which is also the shady side, to be thickly covered with snow and ice. About half a mile above the terminal face a small hanging glacier comes down from the slope of Mount Kinkel, and a little further on a very fine tributary comes in from behind Mount Kinkel and extends back to a snow saddle evidently leading on to the St. James Glacier, a tributary of the Ramsay. On its western side are some very fine ice-cliffs, and the lower part is crossed by numerous crevasses and is very dirty, while from the upper side a well-defined medial moraine takes its origin. This glacier I have called the Cockayne Glacier, after Dr. L. Cockayne, who has done so much work on our alpine vegetation.

About a mile further on another fine tributary comes in from the north side, and I have called it the Heim Glacier, after the well-known Swiss glaciologist, in order to be in keeping with the scheme of nomenclature which Haast followed with regard to names in the locality. It rises in a large snowfield, apparently fairly level, lying between Malcolm Peak in the west, Blair Peak on the north, and an unnamed peak on the east. The ice issues from the amphitheatre, and joins the main glacier by a very fine fall. From the western side a well-marked moraine stretches down the middle of the Lyell Glacier. Malcolm Peak is a fine pointed mountain heavily covered with ice, and with a beautiful hanging glacier dropping down from behind a small dome immediately to the south of the main peak. At this point the floor of the valley is very flat, with the ice slightly crevassed, but it then extends on a generally rising slope right to the base of Mount Tyndall, about three-quarters of a mile further on. This is a fine mountain, strongly reminiscent of the shape of the Matterhorn. It culminates in a rocky peak, with a snow-covered saddle on either side. According to Mr. Earle, who recently visited the locality from the Rangitata and made important topographical discoveries, the western saddle leads to the Wanganui River, flowing to the west coast, while the eastern one leads to the Clyde, one of the main head-waters of the Rangitata. The height of these saddles probably exceeds 6,000 ft., as the floor of the valley at the base of Mount Tyndall reaches 5,000 ft. as measured by aneroid. The amphitheatre which forms the head of the Lyell Glacier is very fine, with Mount Tyndall forming its actual head and Mount Goethe and Malcolm Peak its southern and northern flanks. The length of the glacier cannot exceed five miles at the outside, judging the distance roughly, and considering that our return journey from the base of Mount Tyndall to the terminal face was made in an hour and a half.

This estimate certainly necessitates an alteration in the position of Mount Goethe on the most recent official map, since it is put too far to the

south-west. The mountain called Tyndall by Haast, and pictured in his report on the Rakaia, is not the same Mount Tyndall to which he gave the name from the valley of the Rangitata, nor yet again from the Godley. It is also probable that the Mount Tyndall of the excellent Westland survey is none of the mountains to which Haast gave the name. This is somewhat unfortunate, and appears to result from the mistake made originally by Haast, who thought that he saw the same peak from each of these three great valleys. Mr. Earle has recently pointed out that the mountain called "Tyndall" by Haast when he explored the Rakaia is probably a peak not really marked on the maps, but one to which a new name should be assigned. Dr. Teichelmann has still more recently confirmed this observation in a letter to the author, and says that this peak is called variously McCoy Peak and Mount Nicholson, and that it is not on the main divide, but lies to the east of it.

The Lyell Glacier presents no features of special importance. Its surface is fairly smooth and little crevassed, the roughest portion being that near the confluence of the Cockayne Glacier and its disturbing influence. The lower portion is covered with moraine, which comes principally from those mountains not covered with ice and perpetual snow, but from those specially subject to the action of frost. This weathering-agent attacks the exposed surfaces of the rocks by means of their frequent joints and bedding-planes, and produces in this region a particularly large amount of angular material, which is poured on to the surface of the glaciers by numerous "shingle-slips." Although the Lyell has a thick covering in many places, its moraine is small as compared with that of its near neighbour, the Ramsay.

(ii.) Ramsay Glacier.

(Plate IV, fig. 2.)

This glacier takes its origin in the snowfield on the west side of Louper Peak, between it and Mount Whitcombe. It stretches for six miles in a S.S.W. direction between Mounts Ramsay and Kinkel on the west and the Butler Range on the east, and maintains a direction parallel to that of the valleys on the north of the Rakaia. It receives from the west two important tributaries—(i) the Clarke Glacier, which rises between Mount Westland and Mount Whitcombe, and runs in a north-westerly direction to a low saddle leading to the Upper Wanganui River on the western side of the range; and (ii) the St. James Glacier, which rises between Mounts Kinkel and Ramsay. Although the upper portions are comparatively free from *débris*, the lower three miles is more covered with moraine than any glacier with which I am acquainted. Even the Mueller and Tasman fail to come up to the Ramsay in respect to the size of the blocks and the completeness of the covering. Not only is there an abnormal amount of small material, but angular masses of the size of cottages occur piled together in disorderly heaps. Most of this comes from the precipitous faces of Mounts Ramsay and Whitcombe, which are so steep that little snow can cling to their bare crags, and are therefore rapidly broken up by the action of frost. The amount of material which comes from the Butler Range on the east is of comparatively little importance.

On the east side of the terminal face the Ramsay branch of the Rakaia rises from an ice-cave, but water certainly soaks through from all the face between Mein's Knob and Jim's Knob. The glacier is here just over half a mile wide.

There are clear signs of the decrease in size of the glacier, as abandoned lateral moraines marking old ice-levels occur in places along the valley-walls, and it is extremely probable that at a comparatively recent date it stretched right across the Lyell River till it impinged on the lower slopes of Mein's Knob. This river would then take a course through a tunnel partly under the ice and partly under the edge of the knob. A large part of this has at a fairly recent time slipped away from the face of the bluff and left a narrow chasm which affords a path round the shoulder of the knob, overlooking the river.

(c.) *Absence of Terminal Moraines from Present Glaciers.*

The glaciers of this region, like the great majority of those in New Zealand, are not forming any well-marked terminal moraines. Neither the Fox or the Franz Josef on the west coast nor the Tasman or Mueller on the east have any sign of a terminal moraine; those formed by the Mueller are really lateral moraines formed by a glacier crossing a valley. In all the cases that I have observed the *débris* which reaches the terminal face is removed by the transporting agency of powerful streams. The Lyell Glacier has no true terminal moraine, and, although the Ramsay Glacier is heavily laden with waste from the neighbouring hills, there is no accumulation in the form of irregular heaps or a barrier at its end; in fact, there is no sign of such a moraine in the Rakaia Valley till the plains are reached. The Cameron Glacier is not forming a terminal moraine at present, although a very well-marked one lies some 800 yards away from the present face. In the Rangitata Valley an exceptionally distinct one occurs about five miles from the terminal of the glaciers. These moraines were formed when the glacier reached further down the valleys than now, but there must have been some difference in the then conditions which promoted the accumulation of *débris* across a valley, when no such accumulations are forming now. The actual circumstances under which terminal moraines are formed seem somewhat obscure. They are taken for granted as a feature of every glacier, but such is not the case. Why is it that the Fox and Franz Josef have formed huge terminal moraines some distance away from the ice, a little further down the valley, and are not forming any now? If the Ramsay Glacier, heavily encumbered as it is, were to disappear, and the loads of waste that lies on it were to coat the surface of the ground, there would be no sign of the heaps which characterize true terminal moraines. The question must resolve itself into one of supply and demand. If the glacier furnishes material in such quantity that the river can remove it, then no moraine will form. If for any cause the supply becomes greater or the volume of the river less, then accumulations will take place. At the present time the material supplied to the Ramsay Glacier is excessive and a moraine should result, but no moraine is forming. On the Lyell the amount is not really great, and its front is swept quite clear. It may be that our rivers have such a steep bed that they are equal to removing even the fullest supply that the glaciers can furnish. But when the case of the two great West Coast glaciers is considered this explanation does not appear quite so satisfactory. In former times, when forming great moraines, they had the same steep slope as now. The same remark also applies to the Cameron. We must suppose, therefore, that a little time ago the conditions were such as promoted the formation of enormous supplies of waste. This may be explained by an increase in the height of the

mountains, due to an elevation of the land, rendering larger areas subject to the action of heavy frost, which is the chief agent of denudation on mountain areas. The same effect may be produced by supposing the climate to have been slightly more rigorous than that existing at present. In a former paper on the "Terrace-development in the Valleys of the Canterbury Rivers" I have already noted as a deduction from the condition of shingle fans, and from peculiarities in the form of the river-beds, that there has been a falling-off in the supply of waste, and this observation on the moraines tends in the same direction. In the paper referred to, I attributed this falling-off to a lowering of the land, just as I attributed the severer glaciation to elevation of the land. My present opinion is by no means decided that this was the predominating cause. Elevation certainly occurred, and this would assist other causes tending in the same direction, such as a modification of the climate. Whether the retreat of the glaciers has been due to a lowering of the land or to an amelioration of the climate, the supply of waste has fallen off, as well as the supply of snow, which determines the existence of the glaciers. If the former falls off in a higher ratio, then there will be no moraines; if, however, the waste increases in a higher ratio than that of the transporting-power of the streams resulting from the melting of the snow, moraines will certainly form. This will occur in general when there is a temporary advance of the ice due to climatic or other causes, just as failure to form moraines will occur during retreat. The frequent absence of moraines from the front of Pleistocene ice-sheets may perhaps be explained by the amount of water formed at their terminals being in excess—probably much in excess—of that necessary to transport the relatively small amount of material which usually accumulates on the surface of the ice-sheet and beneath it.

6. Former Glaciation.

(*a.*) *General.*

It may be inferred from the statements made previously in this article that in former times the country was subjected to a more severe glaciation. The proofs of the former extension of the ice are found on every hand. These may be summarized as follows: Old moraines, *roches moutonnées*, striated surfaces, ice-shorn and ice-terraced slopes, valleys with characteristic U section with truncated and semi-truncated spurs, and spurs with triangular facets. A deposit of boulder-clay with large angular fragments is found at the Potts River, where, according to Haast, there are the most characteristic subglacial deposits to be found in New Zealand. I do not know of any discovery recorded later which necessitates a revision of this statement.

The limits of this glaciation to the eastward were in all probability not beyond the line of the foothills flanking the eastern mountains. Glaciers certainly came through the Ashburton Gorge down to the neighbourhood of the Mount Somers Township, since immediately behind it there is a terrace formed of washed material containing large angular blocks which look like those deposited in streams at the immediate front of a glacier. The smoothed and rounded hills in the locality are also suggestive of ice-action. But the occurrence of lateral moraines high up on the hills flanking the gorge on the south is conclusive proof of its presence, and shows that even in that part of the country there was very great thickness of ice at the maximum glaciation. On the northern side of Mount Hutt, glaciers

came through the Rakaia Gorge on to the plains near the Point Station. Haast says that they extended several miles on to the plains, but I am inclined to think that the evidence for this extreme extension is of a somewhat doubtful character, and what he took for morainic accumulations are fluvio-glacial deposits such as are formed by the powerful streams issuing from the edge on an ice-sheet or glacier. In the neighbourhood of the Point Station there are very extensive areas covered with reassorted detritus arranged in irregular heaps of the Drumlin type, showing that the glacier reached almost to that point, and so must have been over sixty miles in length.

In the Rangitata Valley there are undoubted signs of glaciation where the river debouches on to the plains.

Thus the valleys of the Rakaia and Rangitata were filled with exceedingly large glaciers of the ordinary type, but there is no indication that they approached even distantly to the character of an ice-sheet. In the Lake Heron Valley, with its flat floor and wide cross-section, and its relatively higher altitude, they possessed in certain respects a remote resemblance to an ice-sheet of very small dimensions. The area of land in this valley formerly covered with glaciers extended twenty miles in length by at least eight in breadth; but it must be regarded as a great basin filled principally with snow and *névé* fields at the height of the glaciation rather than a true ice-sheet.

(*b.*) *Old Moraines.*

The chief morainic accumulations are those of the Hakatere and its tributary valleys. Here for over several square miles the floor is covered with irregular heaps of angular material forming the terminal moraines of ancient glaciers; fairly extensive accumulations occur at various points in the Cameron Valley and at its outlet, in the Upper Ashburton Valley, as well as on the north side of Lake Heron, on the slopes of the Sugarloaf, but these are insignificant when compared to the square miles of *débris* lying to the south of the lake, and forming the great dam which acts as the containing-wall on that side. This great deposit stretches across the floor of the valley, and also extends down it for several miles towards the Clent Hills Station and the Ashburton River, especially on the north-west side of the valley. At one place this has been cut through by a former river-channel which drained the lake, and has left as proofs of its former existence high terraces on either side of its bed. In the floor of the great deserted channel a tiny stream meanders, an insignificant remnant of the great river which at one time flowed from the front of the glacier and for a time served as the means of discharge for the surplus water of the greater Lake Heron.

The next extensive deposit is that which stretches from Hakatere Station right through to the Potts River. For miles the floor of this stream-deserted valley is covered with heaps of angular material. It forms a great barrier across the upper end of the Pudding Stone Valley and on the low saddles which lead to the small valleys behind Mount Possession Station. These were terminal moraines of the ice as it halted in its retreat from the eastern hills of the area.

Apart from these, the only morainic accumulations of any extent are those lateral moraines which mark the high ice-level on the valley-sides. They are common up the Rangitata and in the valley leading from Hakatere to the Potts, and occasionally in other places. A frequent position is

rounding the shoulder of a spur, or in the wider part of a valley, where in some corner or indentation in the side they have not been exposed to the full action of denuding and transporting agents. They sometimes occur near the mouth of tributary streams coming into a larger valley. These moraines are at times the terminals of the tributary glaciers, but in some cases they are undoubted lateral moraines of the main glacier. The incoming stream of ice has pushed the main glacier over, and accumulations have taken place on both sides of the tributary, especially on its upper side, and the stream of water which has succeeded the glacier has pushed over the main river in its turn, thus preserving the moraines at that spot, even if they have been removed from other parts of the valley by the transporting action of the river.

A peculiarity may sometimes be observed in the arrangement of the blocks of the lateral moraines which is occasionally useful for differentiating them from terminal moraines. In the latter case there is no order or arrangement—the blocks lie quite at haphazard; but in the case of lateral moraines the blocks usually lie with their long axes parallel to the direction of motion, and also the upper ones overlap the lower ones like pebbles in a stream. This arrangement is certainly rude at times, but it is quite distinct, and is brought about by the movement of the glacier causing a drag on the heavy accumulations between it and the valley-sides where the latter are not in close contact with the ice, such as at those parts where the valley is slightly wider, or where the glacier is showing signs of decreasing activity near its terminal face.

Thin coatings of moraine also lie on the tops of truncated and semi-truncated spurs left by the receding tide of ice. An excellent example of this occurs on the downs behind Prospect Hill, in the angle between the Rakaia and the Lake Stream (Plate V, fig. 2).

(*c.*) *Ice-planed Slopes.*

These are a special feature of the Lake Heron Valley, all the north-west side of which is smoothed and terraced to a remarkable extent (Plate V, fig. 1), recalling the photographs which appear in Professor Park's bulletin on the Wakatipu district. The similarity of the landscape in the two districts is really surprising. Judging from the shape and slope of the glacier-shelves, the ice must have come from the north, even in that part of the valley adjacent to the Rakaia. This undoubtedly proves that a section of the Great Rakaia Glacier overflowed from the present Rakaia basin, came up the valley of the Lake Stream, and left its marks on the ice-planed hills towards Hakatere. As it overflowed the Clent Hills towards the Stour River it modified the landscape similarly.

(*d.*) *Roches Moutonnées.*

Ice-shorn rocks are a feature of certain parts of the land-surface. They occur in the Lake Heron Valley between the Clent Hills Station and Lake Heron, where their long scour slopes presented towards the north clearly indicate the direction from which the ice has come. In the Rakaia they appear at the sides of the river-beds, but lower down we find Double Hill and Little Double Hill, typical *roches moutonnées,* in the actual floor of the valley. In the Rangitata, the Jumped-up Downs, and the isolated hills in the floor of the valley between them and the Potts are also excellent examples of this result of glaciation. Clearly marked striae are rarely seen but if the surface coating of soil and *débris* were removed they

would appear plentifully, since the rocks are hard and resistant enough to retain the finest markings. *Roches moutonnées* of small size are very infrequent, and the larger ones grade into the general ice-shorn slopes and truncated spurs.

(*e.*) *Truncated and Semi-truncated Spurs.*

These are exhibited in all stages of development in the Rakaia Valley. Its sides have been straightened so that their alignment is almost perfect, and the spurs exhibit the triangular facets which result from the shearing-off of their ends. I have shown elsewhere that such a land-form is stable, and persists after other features resulting from glaciation have been destroyed by denuding agents. Even in the Ashburton Gorge these faceted spurs occur in an almost perfect condition. In the earlier stages, if the valley is not very deep, the mode of truncation of the spur appears to be that a series of strips is planed off the ends from above downwards. Shelves left in an unfinished condition suggest that this is a common procedure, although erosion at the base of the spur and along its whole face must occur as well. These processes heighten the steep slope that the end of the spur presents to the main valley, and it must become so high in time that the glacier cannot overtop it, so that the valley can be widened only by scouring away the end and by eroding the base.

The angle of slope of the end of the spur is related to the width of the valley and the amount of ice passing through a particular cross-section. Where the valley is wider in its pre-glacial stage and the supply of ice is small the walls flare more and the angle of slope is not so steep. Where the valley is narrow and the supply of ice is great the angle approaches the perpendicular. An exceptional instance of this action is seen on the north side of Milford Sound, where the Lion Rock is vertical for hundreds, even thousands, of feet. The height of the face of the spur is increased by the deepening of the valley as the ice erodes its bed, and the slope tends to become more and more steep as the valley is more deeply cut and the stream of ice more confined, a result quite analogous to that produced by a river when actively eroding its bed. In some cases the spurs are only partially truncated, and specially so where a strongly marked ridge is overridden by ice coming in from a tributary or round a pronounced bend in the valley. Both Mein's Knob and Jim's Knob, at the head of the Rakaia River, owe their form to this action, and in their case the result has been intensified by the mutual interference of the Lyell and Ramsay Glaciers as they forced their way together through the somewhat narrow valley just below their junction. The ice has thus been crowded up on the slopes of the spurs at the sides, and they both show the well-defined notch cut close to the valley-wall by the more active erosion of the ice as it swings round a corner. If this process is carried further it produces a rounded knob separated from the main portion of the spur. Prospect Hill (Plate V, fig. 2), at the junction of the Lake Stream and the Rakaia, owes its form to a part of the Rakaia Glacier turning out of the main valley in the direction of Lake Heron and cutting off the projecting spur on the western side. It is a splendid example of a semi-detached knob, and the downs behind it are the remnant of the spur which has been reduced, but still remains at a height of 600 ft. above the present floor of the main valley. In a former plateau country in which the valleys are well developed the ice frequently crosses saddles and cuts them down to a greater or less extent. In this way ridges are often partially or completely separated from the mountain mass which they were originally

connected with such ridges will generally lie parallel to the direction of the ice-flow, and will be abraded and reduced in height if the ice can pass over them and reduced in length where it cannot pass over them. Thus all stages appear between the long spur and the conical hill. In the valley of the Waimakariri and in the Lake Coleridge basin on the north side of the Rakaia River the intermediate forms occur in perfect sequence, but in the Lake Heron district the destruction has been more complete and the spurs grade into low flat *roches moutonnées* or into ice-planed slopes. An instance of such a cut-out spur can be seen in Shaggy Hill, five miles north of Lake Heron, where lay the original divide between the Ashburton and Rakaia basins, which has been lowered and one of the spurs reduced to an immense *roche moutonnée*. An advanced stage in the destruction of such a ridge occurs in the Sugarloaf, at Lake Heron. This mass is evidently the remains of a spur which divided two valleys, and which projected above the stream of ice as a nunatak even at its maximum, for its top shows no sign of glaciation, while its sides and northern end have been rasped and smoothed away.

(f.) *Valley-features.*

The profiles and cross-sections of the valleys are those produced by the action of glaciers on a matured stream system. Their special features, such as the alignment of the valley-walls, the truncation of the spurs, and the presence of glacier-shelves, *roches moutonnées* and moraines, have been just dealt with. The surface features of the Lake Heron Valley have been little altered since the glaciation, and this suggests that it cannot have occurred at a distant period of time, geologically speaking. The Rakaia Valley has been subject to the action of a great river overcharged with detrital matter, so that the U-shaped floor has been filled to considerable depth with material derived from the glaciers at its head and from tributary streams and shingle-slips. The U-shaped form has thus been modified and the floor has been flattened by the deposits of an aggrading stream. The actual depth of the deposit is unknown at present, but it must amount in places to hundreds of feet.

The cross-sections of the valleys present some interesting features. Above the level of the truncated spurs, or above the level to which the glaciers filled the valleys—and this applies to the tributaries with equal force—the slopes become concave in shape (Plate VI, fig. 1). These are to be found in the whole mountain area of Canterbury. At higher levels they are occupied for a part of the year with snow, and they seem to owe their origin to its weathering action. By its presence the surface of the rocks is maintained in a moist condition, and slow but sure chemical and other erosion takes place, a shell-like hollow being eventually formed. The snow forms these hollows, in which afterwards, as weathering action proceeds, thick drifts accumulate. If the climate grows more rigorous or other circumstances promote the progressive accumulation of snow, then a small glacier forms. Such conchoidal slopes, developed under former more severe climatic conditions, are the favourite location of our moisture-loving alpine plants and our mountain meadows, with their rich displays of *Ranunculus* and *Ourisia*.

(g.) *Cirque Glaciers in Relation to the Formation of Passes and the Dissection of Spurs.*

In former times, when the conditions favoured the accumulation of thick drifts of snow, these concave hollows were gradually filled with ice

Fig. 1.—Ice-scoured and Terraced Lands at Lake Heron Valley.

Fig. 2.—Prospect Hill, with Moraines at Junction of the Lake Stream and the Rakaia.

Face p. 9[illegible]

Fig. 1.—Valley of Louper Stream, leading to Whitcombe Pass.

Showing ice-eroded lower slopes and conchoidal snow slopes above them. The Rakaia River bed and characteristic fan of the Louper Stream in the foreground, Louper Peak in the background.

Fig. 2.—Ice-scoured Pothole at Junction of the Lake Stream and the Ra

and became corrie glaciers. The process of erosion begun by the snow was continued by the ice, but on different lines. The walls and sides were sapped back and the basins were enlarged till the glaciers they held became small ones of the valley type. As this went on, the floor was eroded deeper and deeper at the head, while little erosion went on near the lip, so that when the ice disappeared the hollow left behind was usually occupied by a lake. This seems to be the ordinary course of the development of a corrie glacier and the hollow usually associated with it, according to the most advanced school of physiographers; but there is a weighty body of opinion totally opposed to the idea that corrie glaciers are potent agents in modifying landscapes. Although the present writer is somewhat chary of expressing a dogmatic opinion on a subject which has lead to so much controversy, his experience in the glaciated districts of this country, notably in the Sounds region, leads him to think that the course of development outlined above accounts best for the phenomena that occur.

By granting the capacity of glaciers of this type to sap back their heads one can explain the formation of the jagged and razor-backed ridges which so frequently separate the head of one tributary glacier from that of its neighbour across a divide. The usual sequence of events in such a case appears to be as follows: First there is a ridge, more or less rounded, with two shell-like hollows containing snow on either side. In process of time a corrie glacier forms. Then sapping goes on, and the divide becomes narrower and narrower; then it is a mere wall, and finally this collapses and a saddle results. At the head of the Rakaia there are existent glaciers which show all stages of this development and furnish some idea of the modification which results from their action on mountain-ridges; but in those parts from which the glaciers have retreated the landscape-forms resulting from this action can be readily noted and studied in detail. We see here all the stages from the shell-like hollows, through the razor-backed ridges, to the final "pass" form. The latter are usually U-shaped in cross-section, but they tend to become parabolic by the accumulation on their floors of detritus shed from the walls. It seems possible that the isolated ridges which so frequently occur in all the great valleys of Canterbury owe their dissection to this process, especially as the main valleys run across the strike and the cross-valleys are developed in the soft beds parallel with it, these beds furnishing an opportunity for snow to weather rapidly the shell-like hollow where thicker and more persistent drifts can gather. When the lowering of the divide has been accomplished by this action the main glaciers occasionally pass through them, especially if they are on the increase; they are cut down further still by the usual methods of glacier erosion. The occurrence of parallel or subparallel ridges in the mountainous district of Canterbury are of such a frequent occurrence, and such an important feature of the landscape, that their formation appears to be connected with the former glaciation, and the explanation I have given seems to me to be the most satisfactory way of accounting for their existence.

NOTE.—Since writing the above I have seen an interesting paper by Professor W. H. Hobbs, of Michigan University, published in the *Geographical Journal* for February, 1910, which emphasizes the important effect produced on the mountain topography by the sapping-back of the walls of corrie glaciers. Most of the landscape-features mentioned by Professor Hobbs are exemplified in that part of the mountain district of

Canterbury which has been subject to glaciation in the past, or where glaciers occur now. The conclusions I have come to were made quite independently, and this may perhaps lend additional weight to them, as they are the result of observations in a country far distant from that where Professor Hobbs made his. Professor W. M. Davis, of Harvard University, has lately informed me in a letter that Matthes was the first to point out the relation of corrie glaciers to saddles and passes, in a report on the glaciation of the Big Horn Mountains (United States Geol. Survey, 21st Annual Report, 1899–1900).

(*h.*) *Glacier Potholes.*

(Plate VI, fig. 2.)

A very interesting and suggestive landscape-form occurs at the junction of the Lake Stream with the Rakaia. This is a round hollow over 300 ft. deep and about half a mile across, with the whole interior cut into horizontal or nearly horizontal shelves. These have evidently been produced by the erosion of ice moving in an approximately circular direction in horizontal planes. There is a remarkable resemblance to a pothole in an ordinary river, and the occurrence serves to emphasize the close resemblance that exists under certain circumstances between the erosion of a river and that of a glacier.

If the similarity in the action of the two streams be granted, the explanation of the formation of the hollow is quite easy. A portion of the great Rakaia Glacier running from west to east turned south just above the Lake Stream, rounded the spur at Prospect Hill, and turned up the valley towards Lake Heron. The ice impinged against the massive hill to the east of that valley, and just at the junction an eddy was formed which scoured out the hole, the horizontal terraces being a result of that gyratory motion. When the ice disappeared a rock-bound lake occupied the hole, which has since been emptied through the degradation of the barrier by the outflowing stream. An exactly analogous case occurs at the junction of the Cass River with the Waimakariri. The Waimakariri Glacier at the time of its greatest power flowed from west to east, and on reaching Goldeney's Saddle, about six miles below the Bealey, overrode the end of the spur and turned south-east into the valley towards Lake Pearson and the head of Sloven's Creek, following the line of the Midland Railway. On the east side of Goldeney's Saddle it formed a rock-bound basin exactly similar to the one in the Rakaia, but not quite so perfect. The Cass River now runs through it, and passes through a notch in the rim towards the Waimakariri. The whole locality presents a remarkable resemblance to that of the Rakaia. Goldeney's Saddle and its semi-detached knob corresponds exactly to Prospect Hill. There is a mountain mass on the east side of the inflowing stream, against which a part of a great glacier impinged. The rock-bound and ice-scoured pool with horizontal terraces lies between the two, no doubt in both cases forming a lake on the retreat of the ice, and then this has been emptied in both cases by the erosive action of a stream coming in from the south. Both occurrences emphasize the erosive action of the ice under similar conditions, and its capacity to scour out rock-bound basins in circumstances such as would favour the formation of eddies if water and not ice were the moving element. This action explains the formation of many of the rock-bound ponds and small lakes which occur freely in countries which have been glaciated. Numerous instances of

this action can be seen in the Sounds district on the south-west of the South Island of New Zealand, and those at the head of George Sound may be specially cited as furnishing excellent examples of the phenomenon.

(i.) *Efficiency of Glaciers as Eroding Agents: Evidence furnished by the Locality.*

A consideration of the glaciation of the area would be incomplete without some reference, however slight, to the evidence bearing on the much-discussed problem of the efficiency of glaciers as erosive agents. It is admitted, even by those who admit least, that glaciers act as flexible rasps, and remove the minor inequalities of the land-surface. The landscapes of the area under consideration give abundant evidence of this, but they are not so decided on the major question of the power of glaciers to excavate the beds on which they lie. It appears to the present writer that corrie glaciers, instead of acting as protective agents, as suggested by some observers of wide experience, do actively erode their beds, and also their side walls and their heads, especially the last, much more rapidly than the streams which issue from them erode their beds. Also, small valley glaciers have this power as well, and enlarge the amphitheatres at their heads at a more rapid rate than the rivers which they give birth to erode their valleys, so that these are narrow in their lower reaches, whereas their upper portions, which have till recently been filled with ice, are wide and of basinlike form. In this case, however, full consideration must be given to the possible neutralization of the erosive power of a stream overloaded with waste, as many of these streams are. Still, after making full allowance for this, there appears to be ample proof that ice in corrie glaciers and in the smaller valley ones related to them does not act as a protecting but as a powerful erosive agent.

There are other matters suggested by the landscape-forms of the Rakaia Valley which require very careful consideration in this connection, and apparently point in the opposite direction. First of all, there is a marked absence of waterfalls and hanging valleys. On the northern side of the main river the numerous parallel streams which rise in the main divide and flow south enter at grade (Plate VI, fig. 2), and the same is true of those on the southern bank, although they are few in number, and, with the exception of the Lake Stream, are much smaller. At first sight it would appear that the glaciers have only acted as a rasp, and modified but slightly the features of the previous valley system, were their efficiency as erosive agents not clearly indicated by the basin which occurs in the main valley of the Rakaia below the intake of the Lake Stream. Here there is a great hollow over twenty miles in length and 500 ft. deep in places, shut in at its lower extremity by a rock wall, which was once occupied by a great glacier and was subsequently either partially or wholly filled with silt. It was finally drained by the outflowing river cutting down a narrow gorge through the lip of the basin, a result hastened by the pouring-in of enormous supplies of waste as the glaciers retreated up the valley. This landscape-form is reproduced perfectly, but on a smaller scale, in the Upper Ashburton Valley. In this case it seems impossible to attribute the rock-barred hollow to any other cause than basal excavation by a glacier. Exactly similar features can be seen in the valleys of the Rangitata and the Waimakariri, and they no doubt occur in the less-advanced condition in the valleys of the Tasman and Godley, in the basin of the Waitaki, further south. Here lakes still occupy basins once filled with ice; but they also, like the basins further

north, are destined to obliteration by the rapid lowering of their outlets and by filling up by detritus poured in by waste-laden streams. There appears to be no reasonable doubt that in these cases, too, water has collected in the hollows excavated by former glaciers.

The only other hypothesis which may be put forward to explain these rock-bound basins is the somewhat unsatisfactory one of faulting or warping. Although a system of radiating faults has been suggested as the reason for the peculiar orientation of the valleys of Canterbury (McKay, Geological Report. 1892), the basins, as they occur, could only be explained by a series of peripheral faults or lines of warping disposed in a rude circular arrangement around a centre. Of this there is no evidence at present, and, unless the occurrence of earth-movements such as these can be thoroughly demonstrated, it seems best to adhere for the present to glacier excavation as the most satisfactory explanation for the formation of these lake-basins. Further, if earth-movements are a prime cause of their formation, why are lakes found only in those parts of the South Island which have till recently been subjected to the action of ice, and not found in parts which have undoubtedly experienced very recent faulting and other dislocation?

In the face of this contention the absence of waterfalls and hanging valleys and the accordance of the grade of the tributaries with that of the main stream may be accounted for in two ways:—

(1.) That the solid floors are really discordant, but the valley of the main stream and the lower part of the tributary have been so filled with detritus that the discordance is completely masked. We have really no idea of the depth to which these valleys have been filled with waste, but it may amount to hundreds of feet. Borings in the bed of the Waimakariri in a similarly situated position disclosed nothing but shingle for 30 ft. This is a very shallow depth, but it represents all that has been done in the way of exploration by boring in these river-beds. If the thickness be very great, as it probably is, then the tributary valleys of the Rakaia may resemble, perhaps remotely, the tributary valleys of the Milford Sound, such as Sinbad Valley and Harrison's Cove, which are accordant with the level of the sea, or nearly so, but markedly discordant with the floor of the sound.

(2.) It is possible from the arrangement of the tributary valleys that they were filled with ice long after it retreated from the main valley. The latter for some distance makes a very small angle with the direction of the main range, where the snow collects and forms glaciers. At the present time the Ramsay Glacier runs at right angles to the main valley, and ends on reaching it. The same would be true for every tributary on the northern side of the river at some previous time. At one stage in the retreat of the ice a great river would run across the terminal faces of several large glaciers coming in from the north and occupying a series of parallel valleys. Ice erosion would therefore proceed in them after it had ceased in the main valley. The same accordance in the tributaries can be observed in the Waimakariri, and the same explanation fits this case as well. However, there are facts which undoubtedly lean to the other side. The valley system had no doubt reached a mature stage, and the valleys were accordant before they were modified by glacier-action, and the fact that they are still accordant may be taken as proof that glaciers have little power of differential erosion. If it were not for the evidence that they have eroded their beds lower down the valley, I should be inclined to say that the advantage lay with the opponents of ice erosion. My opinion is, however, greatly influenced

by experience in the fiord region of the south-west of New Zealand, where the landscape-features are apparently inexplicable on any hypothesis which denies to glaciers the possession of marked powers of excavation, though it is possible that we are not aware of all the factors which control this power.

7. CHANGES IN DRAINAGE IN THE RAKAIA VALLEY.

The case of the change of drainage in connection with the Lake Heron Valley has been referred to several times previously. In the pre-glacial river system the Cameron undoubtedly drained south toward the Ashburton, and in all probability a small tributary ran north to the Rakaia from a divide between that river and Lake Heron. This divide was lowered by glacier-action, and the drainage was reversed. The change resulted largely from two causes—viz., (1) the piling-up of a barrier across the Lake Heron Valley at the south end of the lake, and (2) the lowering of the bed of the Rakaia by the erosion of its great valley glacier. The Lake Stream has thus been given a high gradient, and it has therefore rapidly removed any barriers that may have existed to the north of the lake, and has degraded the rocky ridge which formed the lake's containing-wall on that side, so that its size has been materially reduced from that which it had immediately succeeding the retreat of the glaciers. The great swamp north of Lake Heron is the old bed of that lake in its extended form.

The overdeepening of the bed of the Rakaia also allowed the small rock-bound lake at the junction of the Lake Stream and the main river to be emptied as well.

In other parts of the Rakaia Valley drainage anomalies occur, the most remarkable being that of Lake Coleridge. This lake occupies a valley parallel to that of the Rakaia, down which the Wilberforce River and glacier once flowed. A great terminal moraine was left by this glacier, which was also added to by a lateral one from the main Rakaia, across the south end of the lake, blocking the drainage in that direction. The effect was accentuated by the lowering of a saddle in the ridge between the upper end of the lake and the Rakaia Valley, so that at one stage the glacier flowed over this and reduced it so far that the Wilberforce River deserted its old bed and joined the Rakaia ten miles further up stream. The lake followed this direction too, and now discharges at its upper end by a small stream which joins the Harper River and flows into the Wilberforce. The Harper River also once flowed down a valley to the east of the Lake Coleridge Valley and parallel with it; but it, too, turned over a low saddle in the direction of the Rakaia, and flowed through the Wilberforce gap. Other small streams have behaved in a similar way, and have turned from their own valleys through gaps in the ridges that once separated their own valleys from the Coleridge Valley. These gaps were in all probability formed primarily by the action of corrie glaciers in the manner described previously. These remarkable changes in drainage seem to have been made possible by the overdeepening of the Rakaia Valley by its more powerful glacier below the level of the parallel valleys, thus providing a lower temporary base-level for the tributary streams. The same fact is also true to a modified extent of the valley to the east of Lake Coleridge, which has been eroded deeper than they have by the large glacier which occupied its floor.

While the Rakaia has been gaining in the upper part of its course as a result of glacier interference, it has lost lower down. Between the Rock-wood Hills and the Big Ben Range there is a wide valley which was occupied

once by a large glacier which flowed south-west, as evidenced by the smoothed slopes of Fighting Hill near its junction with the Rakaia. The outlet of the valley is very wide and open towards the Rakaia, but it is partially blocked by a large moraine, partly a terminal of the glacier which issued from this valley, and partly a lateral of the main glacier. This ponded back a large lake in the basin once occupied by the glacier, which secured an outlet not by the Rakaia, but by the Selwyn Valley—a result no doubt aided by the active erosion of the latter stream, which enabled it to cut back its head through the range of foothills and to draw on the basin in the rear. The existence of this lake is demonstrated by the deposit of glacial silt which occupies a part of the floor of the emptied basin near the High Peak Station. The Selwyn now flows from the valley through a narrow gorge of more recent date than its upper basin, and it has gathered to itself all the drainage belonging to this basin which once added to the Rakaia. The Rakaia Glacier has thus been directly or indirectly responsible for several remarkable changes in the drainage directions in its basin and those of its immediate neighbours.

8. Totara Forest.

A very striking feature of the Upper Rakaia Valley is the forest, composed chiefly of totara (*Podocarpus Hallii*), which clothes the hillsides for miles on the north bank of the river, and which occurs in large patches on the southern bank (see Plate VII, fig. 1). In this locality the wet westerly winds reach well across the main divide before they become parching and dry with the usual characters of the Canterbury north-wester, and the mountain ranges on the south of the Rakaia shelter the upper part of the valley from cold southerlies; so that the conditions are thus favourable to the growth of this rain-forest tree. The patch in the Rakaia is but the remnant of an ancient forest containing totara which extended over a wide area on the eastern side of the range, and reached southward through the Mackenzie country into Central Otago, the important bearing of which on the question of post-glacial climates is considered by the author in another paper in this volume. Further details regarding this plant formation will be found on page 363.

PART II.—PLANT ECOLOGY.

By L. Cockayne, Ph.D., F.L.S., and R. M. Laing, M.A., B.Sc.

[*Read before the Philosophical Institute of Canterbury, 5th October, 1910.*]

1. Introduction.

Very little has been published regarding the botany of the Rakaia, Ashburton, and Rangitata Valleys and the mountains adjacent. Sir Julius von Haast* made considerable collections of the plants during his early explorations in 1861, 1864, 1865, and 1866 (Haast, 1879), and these were determined by Sir Joseph Hooker, the new species being described in the "Handbook of the New Zealand Flora," while the rarer species are

* In his first expedition Haast was accompanied by Dr. A. Sinclair, who was, unfortunately, drowned in the Rangitata River, falling, as Haast writes, "a victim to his zeal for his cherished science."

mentioned in the same work. Haast (1866) noted a few of the plants of Browning's Pass, and calls attention to the subalpine scrub on Mein's Knob, describing his passage through it as "a herculean task." Mr. J. B. Armstrong (1879) described several new species from material collected by Mr. J. F. Armstrong, who, with the late Mr. W. Gray, of Governor's Bay, had made an excursion to the Rangitata Valley in 1869. These species were, for the most part, again described by J. B. Armstrong in the "Transactions of the New Zealand Institute" (1881). Mr. R. Brown, of Christchurch, accompanied by Mr. F. N. Adams, botanized in the Wilberforce Valley in 1885, following the Moa Creek to its source. A popular account of the excursion was written by the latter, enumerating some of the plants met with—*e.g.*, *Hymenophyllum Mallingii*, *Alsophila Colensoi*, *Polystichum cystotegia*, *Ranunculus Godleyanus* (abundant), *Veronica macrantha* (Adams, 1885). *Libocedrus Bidwillii* is stated to be the leading forest-tree. Brown published his results later (1894, 1895, 1899), describing several new species of mosses. During the progress of the present geological survey of New Zealand a few plants were collected in the vicinity of Browning's Pass, and these, identified by Mr. A. H. Cockayne, are published in the report dealing with the "Hokitika Sheet" (Bell and Fraser 1906, p. 101).

The authors visited the Arrowsmith district in the summer of 1909–10, but independently of one another, and at different times. Laing examined the vegetation of Mount Potts and the adjacent parts of the Rangitata and Clyde Valleys, and also the Cameron Valley to its glacier; Cockayne, who had the special advantage of Mr. R. Speight's company and geological knowledge, paid attention to the country in the vicinity of Lake Heron, and thence to the neighbourhood of Mein's Knob, on the south side of the River Rakaia, opposite the terminal face of the Ramsay Glacier, and for the account of the associations, &c., of that part of the district he is alone responsible. Both authors studied the plant covering of the lower Ashburton Gorge, and the upper Ashburton Plain as far as the stony bed of the River Cameron. Only a few weeks were spent on the work, even when both excursions are considered. It is plain, therefore, that but a very superficial knowledge of the district was gained, and were it not that matters of general interest are discussed, and formations considered, which concern also other river-valleys of eastern Canterbury, &c., with which we are better acquainted, and which also belong to the glaciated area, this paper would not have appeared.

The term "Arrowsmith district" is used in a broad sense. It includes not merely the actual range itself, but portions of the adjacent country, including the mountains lying to the east and north of the upper Ashburton Plain; but its topography and geology is sufficiently described in Part I. It must, however, be pointed out that the word "district" is not used in its phytogeographical sense, the area dealt with including, in point of fact, portions of two botanical districts.

2. PRIMARY CAUSES AFFECTING THE CHARACTER AND DISTRIBUTION OF THE VEGETATION.

(A.) THE GLACIAL PERIOD.

All authorities agree that the present glaciers, extensive though they are, represent a fraction merely of their former area: the only point in dispute is as to how far they extended into the lower country. But with regard to phytogeography the extent of the glaciation matters little, so long

as sufficient room is allowed eastwards, southwards, and perhaps westwards, for the plants driven out of the mountains to find a haven of refuge. On the contrary, if it is assumed that an ice-sheet has covered the southern end of Greater New Zealand, *leaving no land eastwards or westwards of the present subantarctic islands*, then, for reasons already given by Cockayne (1909, p. 7), the present distribution of species is inexplicable.

There then remains only to be considered the repeopling of the glaciated area from the east during the retreat of the glaciers and the synchronous advance of the plants. Let us consider, therefore, the state of affairs at the time the terminal faces of the Canterbury glaciers, and of the Rangitata-Rakaia in particular, extended just on to the Canterbury Plain, taking into consideration at the same time the effect of elevation, the generally accepted cause of our glacial period (Hutton, 1900; Haast, 1879; Park, 1910) upon the climate.

Although the glaciers may have extended not merely on to the plain, but even far beyond the foothills, it by no means follows that the eastern ranges (Mount Somers, Mount Hutt, &c.) were altogether ice-clad, or even snow-covered. On the contrary, increase in altitude of the actual Divide would lead to a drier climate on the eastern ranges than the present one, and to a much diminished snowfall, so that it is quite possible, even at the greatest assumed extent of the glaciers (see Park 1909, 1910), these eastern mountains still preserved more or less of their primitive plant covering. But the increase of drought would bring about a semi-desert climate on the east, and, as Diels and Cockayne have shown, the forest-plants would either perish or be modified (Diels, 1896; Cockayne, 1901). So it is assumed that various xeromorphic growth-forms have arisen—*e.g.*, *the divaricating, the flat-stemmed leafless*, &c. On the mountains the drought-conditions would be still more severe, and then may have originated the *Raoulia* cushions of the rocks and the highly differentiated shingle-slip plants.

Whether the above speculations are approximately true or the contrary, the first ground available in quantity for plant-colonization would be the rocky slopes above the ice-line of the valley glaciers, such as are to be seen near any of the large eastern glaciers at the present time. The populating by plants of such ground would be very similar to the evolution of fell-field, treated of below, while the final soil would be formed by slow degrees from the easily disintegrated rock (greywacke, &c.) together with humus from the plants, the plant covering favouring the formation of a true soil.

As the ice retreated, the smoothed lower slopes of the hills, the *roches moutonées*, the moraines, and the valley-floors, much of which would be river-bed, would be by degrees exposed. Soil of a different character to that mentioned above would finally accumulate, and would consist of the wind-blown rock-flour from the river-beds, of the subglacial material (boulder-clay, &c.) which would be left on the rock, &c., as the ice melted, and, in special positions, of extensive deposits of lateral moraine. That the surface soil of the valleys and lower slopes is principally wind-transported (*i.e.*, loess), though beneath there may be clay, is evidenced by what is going on to-day during any dry wind, when clouds of dust rise from the river-beds, but such loess may not infrequently be mixed with other soil.

Clay, formed *in situ* from the underlying rock, does not appear to be a specially important constituent of the soil. For instance, on certain *roches*

moutonnées, as Speight has recently shown (1911), the ice-scratches are still to be seen on the non-disintegrated rock-surface when the boulder-clay and loess are removed, such rock having been preserved from weathering by its special hardness, the softer rock having been removed by ice-action.*

The plant-colonization of a river-bed at the present time must be very similar in character to that of the Pleistocene river-valleys, while the rock-faces left by the ice, where not covered by lateral moraine or boulder-clay, would rapidly become disintegrated and extensive shingle-slips be formed. Here loess would at first play no part in soil-forming: this would not come in till the valley glacier melted, and the earliest associations would probably consist of the higher alpine plants, which would later on be replaced on the drier mountains by steppe-plants. A further cause which would assist the spread of these latter would be the gradual decrease of cold water from the melting cliff glaciers, and the consequently warmer soil.

As the *névé* and ice of the highest summits grew less and less the supply of *débris*, owing to disintegration due to the action of frost, would increase, while at the same time the rivers below would be cutting their deep beds and forming their terraces, plant-occupation going on simultaneously, the invading plants being those from close at hand. Between the new plant covering and the *débris*, whether of disintegrated rock or of river-shingle, there would be a constant battle, the plant covering nevertheless slowly increasing in area. This struggle still goes on, river-fans in particular showing all stages of occupation, destruction, and rejuvenescence. Algae, mosses, and lichens would be the first colonizers to settle down, followed by herbaceous plants and xerophytic shrubs, which together would make the first associations. Trees would come later as soil became more plentiful, but they would occupy only gullies, sheltered terrace-slopes, or ground where shrubs had already settled and some shelter was provided.

(B.) CLIMATE.

Besides the physiographic factor with which is bound up the various edaphic distinctions, climate has played an important part not only in the distribution of species, but in the selection and evolution of growth-forms.

As in other Canterbury river-valleys, there are here two distinct climates, a wet and a dry; or, to give them ecological designations, *a forest and a steppe climate.*

The forest climate occurs only near the source of the Rakaia, extending eastwards for perhaps 5 km. from the dividing range, and marking by an irregular line the average distance reached by the north-west rainfall (see also Cockayne, 1900, pp. 117, 118, and 130–33), the rain especially following a main river-valley. When the wind is blowing a gale from the latter quarter there is frequently not a drop of rain in the vicinity of Lake Heron,† and transpiration conditions are at a maximum, but from the neighbouring heights a heavy rain-storm can be seen in progress in the Rakaia Valley.

To be sure, the steppe climate is far from being really dry, but clear skies with strong insolation are frequent, and *the ever-present wind would demand a much higher rainfall before forest could establish itself naturally.*

* This is just the same as occurs in Europe, &c.

† The great mass of Mount Arrowsmith also keeps back no small amount of rain.

The wind is, indeed, a factor of paramount importance. For several days at a time the north-west gale will rage, accompanied by heavy rain in the west, *but in the east quite dry*. Apart from its powerful effect on transpiration, the wind is strongly antagonistic to tall growths, especially where its presence is most felt, as in narrow river-valleys, and the low growth of the majority of the steppe-plants, as also the divaricating-shrub form, are "adaptations" against both the mechanical and transpiration-promoting action of the wind, whatever their origin in the first instance. The south-west wind is of quite minor importance in the Rakaia Valley, but on the heights it may at first bring more or less snow at any season. In the east its effect is more marked. It is a cold wind, and is frequently accompanied at first by rain on the lower and snow on the higher ground.

The winter snowfall is most felt at above 1,200 m. altitude, and plant-distribution according to altitude, as Cockayne pointed out some years ago (1900, p. 128), depends, in part at any rate, upon the average length of time the snow lies upon the ground. In gullies and hollows where the snow accumulates the higher alpine plants may occur at below their usual altitude. Besides acting as a warm covering to the plants and checking transpiration, snow acts mechanically, especially on the evergreen subalpine shrubs, pressing their branches to the ground. The fell-field herbs and subshrubs are also in places submitted to a great pressure, and look, after the snow has melted, as if a heavy roller had passed over them: but this flattening has no effect on their aftergrowth, the shoots rapidly assuming their usual position when the weight is removed. Very effective is the work of snow in keeping the ground cold during the vegetative season, and thus more than in any other way does it regulate the belts of vegetation and local distribution. Further, its gradual melting leads at the higher levels to a constant supply of soil-water for a considerable period, and this is especially noticeable in hollows which may have a distinctive vegetation dependent partly thereon and partly upon the longer time the snow lies.

Frost occurs at all seasons of the year, and in positions where there is no snow-covering young shoots are exposed to its effect. One and the same species may grow, however, in spots protected or unprotected by snow, and in each be equally undamaged. Certain species of *Celmisia* in winter may be coated with ice, and this will function in checking transpiration. Probably even at the highest altitude the thermometer never sinks below 18° C.,* and we should not be surprised if the average minimum is higher.

With regard to xeromorphy, too much stress cannot be laid on the effect of quite short rainless periods in the wettest mountain climate. Plants accustomed to a wet soil, a moist atmosphere, and a frequent downpour are exposed all on a sudden to quite opposite conditions, the porous soil also rapidly losing its available moisture. In such a case xerophytic structure or form sufficient to ward off the danger of excessive loss of water even for a few days is imperative.

* In 1908–9, when on one occasion the thermometer at Kew sank to 10° Fahr., the previous weather having been mild, *Gaya Lyallii* was destroyed to the ground-level, *Sophora tetraptera* was killed, *Griselinia littoralis*, though escaping the winter frost, was much damaged by the winds of March, and ten species of *Veronica* were killed or severely injured (Kew Bull., 237, 1909). Many other examples could be cited, but this sufficently testifies to the comparatively mild climate of the New Zealand lower subalpine belt at any rate.

3. THE PLANT FORMATIONS.

(A.) General.

Here the term "formation" is used in the generic sense indicated by Warming (1909, p. 140), the fell-field, for instance, being a portion of the general fell-field of New Zealand and of mountains in other parts of the world, while the associations are local, and, though made up of similar growth-forms to those of the formation elsewhere, differ in their floristic components. Subassociations are smaller communities within the association, and within these latter again may be groups of species. Finer distinctions still could be made, but for such a most careful analysis of the vegetation would be required, and this is not demanded or desirable in New Zealand so long as the broad features of so much of the vegetation remain unknown. To estimate rightly the limits of certain associations, and especially subassociations, is not so easy as might be thought.

It must also be pointed out that the study of vegetation should be dynamic, and not static. Associations are not independent creations, but each has its life-history—its birth, its youth, its manhood—and in certain instances its evolution may be seen in progress, especially where there is a rapidly changing topography, as on a river-bed,* or where rock changes to fell-field by way of shingle-slip.

The same climax formation may come into being from different beginnings, or may be the result not of progression, but of reversion. Notwithstanding that an association is part of a series, it is a distinct association for all that, and may be just as much a feature of the landscape as a climax association, from which it differs only in its much shorter life.

(B.) Steppe-climate Formations.

(*a.*) THE STEPPE SERIES.

(1.) *General.*

Steppe, in one or other of its phases, occupies the greater part of the Arrowsmith district up to an average altitude of perhaps 900 m., though this is somewhat exceeded in the east. Above it gives place to fell-field or scrub, according to the rainfall. There is both edaphic and climatic steppe, as also combinations of the two.

The term "steppe" was first used for the New Zealand plant formation in 1908 by Cockayne, when dealing with the volcanic plateau in the North Island; previously the same author had used the term "meadow" for this and other xerophytic formations of grasses and herbs. Laing and Blackwell, however, in 1906 had already shown that "tussock country," as they called it (1906, pp. 3, 4), was a vegetation-form of a different type from meadow proper.† How nearly related the New Zealand steppe may be to that of Warming (1909, pp. 281–88) is another matter. Certainly the rainfall and number of rainy days is much greater than Warming gives for a steppe climate; but it must be borne in mind how greatly a heavy rainfall can be discounted by frequent high winds plus a non-retentive soil. The formation also seems related to Warming's "chersophyte vegetation,"

* See Part I *re* topography of a river-bed.

† "Grass steppe is found where the rain is moderate in amount, but falls only a few days in the year; grass steppe as a rule can be utilized for cultivation without artificial irrigation" (Warming, 1909, p. 274).

but this latter we consider with Tansley (1909) an unsatisfactory class, since, on the one hand, it is evidently very close to steppe, and, on the other, its forms are often altogether artificial.

The land-surface of the mountain steppe consists of hill-slopes; river-beds, sometimes lying deep below the general surface of the land; high river-terraces whose remarkably flat tops are old flood-plains, but whose stony faces slope steeply to the river-bed beneath, heaps of old morainic matter with the surface crumpled and irregular; *roches moutonnées* and river and torrent fans.

The surface soil is a soft silty clay, the loess or semi-loess already spoken of, which is readily denuded, easily moved by the wind, and rapidly becomes dried up. Beneath, the clay may be stiffer, and there is nearly always a porous gravelly and shingly subsoil which frequently comes close to the surface.

(2.) *Succession.*

So far as our observations go, steppe has originated in the following ways:—

(*a.*) Through occupation of actual river-bed, a form of succession easily studied at the present time.

(*β.*) Through disintegration of rock followed either by shingle-slip or by a fan at the mouth of a river or torrent.

(*γ.*) Through occupation of moraine, boulder-clay, or other stranded glacial *débris*.

(*δ.*) Through soil blowing on to a rock-surface which by degrees becomes occupied by plants, these further trapping and holding fresh blown soil.

(*ε.*) Through a shallow lake being turned by various stages into dry land.

(3.) *The Associations.*

(*a.*) Rock.

Unfortunately our notes contain but little regarding the rock-vegetation; in fact, rock-faces are much less in evidence in the steppe belt than in that of shingle-slip and fell-field. The rock-plants, leaving a number of mosses and lichens on one side, are generally species also belonging to the steppe proper, and their numbers depend altogether upon the form of the rock-surface and its capacity for catching blown soil and accumulating humus.

Asplenium Richardi, a fern 5–12 cm. tall, with dark-green rather thick much-cut tufted leaves given off from a short stout rounded caudex, is abundant in shaded hollows of the rock. Tussocks of the grass *Poa caespitosa* and *Festuca rubra* var. are common, even where there is little soil. The small succulent herb *Crassula Sieberiana* is abundant, and the following are also common: *Danthonia semiannularis* (tufted grass with slender involute leaves), *Muehlenbeckia axillaris* (creeping, prostrate, wiry stemmed, small-leaved shrub), *Cardamine heterophylla* (annual herb 10 cm. or less tall with slender decumbent stems and short moderately thick smooth pinnate leaves), *Oxalis corniculata* (prostrate creeping herb with slender matted stems and very small rather thick leaves), *Epilobium pubens* (semi-erect herb with stems suffruticose at base and pubescent leaves about 2·5 cm. long and red beneath), *Anisotome aromatica* (rosette herb with very long fleshy root and moderately thick pinnate linear leaves flattened to rock), *Raoulia australis* (low cushion plant with much-rooting stems and small close tomentose silvery leaves), *Crepis novae-zelandiae* (rosette herb with

moderate-sized thick pinnatifid leaves and stout fleshy root). Various xerophytic shrubs occur on rock—*e.g.*, *Hymenanthera dentata* var. *alpina* (cushion of most rigid stout semi-spinous stems bearing, sparsely, small thick smooth dark-green leaves and with very long deeply descending root), *Carmichaelia robusta* (flat, assimilating leafless stems about 30 cm. tall and very long deeply descending root), *Discaria toumatou* (described further on), *Olearia avicenniaefolia* (shrub-composite form, much-stunted, leaves thick, tomentose).

Besides the above a good many of the steppe-plants may occur on rock, the number varying according to the amount of soil and position of rock-surface with regard to sun and wind.

(*b*.) Fan.

Where gullies or gorges open out on to the plain or river-bed there are fans of *débris*, sometimes of great extent. The vegetation of these depends altogether upon the supply of *débris* brought down by the torrent, and this again is correlated with the plant covering of the gully-walls. Fans are either active or passive, and every transition between the two may be traced. The surface of the fan is much steeper than river-bed in general. There are water-channels but these are usually dry except during heavy rain, the stream being generally underground. The stones are frequently in part very coarse, and are often piled into comparatively high but quite unstable terraces, liable during any flood to damage or absolute destruction.

The vegetation commences with the appearance of certain herbs whose "seeds" are wind-borne, and the formation is markedly open. Competition is altogether absent. These first-comers are: Erect *Epilobia* (*E. melanocaulon*, *E. microphyllum*), creeping mat-forming *Epilobia* with slender interlacing rooting stems (*E. pedunculare* in various forms, *E. nerterioides*), herbaceous species of low cushion or rounded mat-forming *Raoulias* (*R. tenuicaulis*, *R. australis*, *R. lutescens*), and the curious half-dead-looking grey-coloured cupressoid shrub *Helichrysum depressum*, some 40 cm. tall, with spreading branches bearing a few closely appressed woolly scale leaves. As the substratum becomes stable the tussock-grasses *Poa caespitosa* and *Festuca rubra* var., one or both, appear, probably occupying first of all a soil-making *Raoulia* cushion or patch; *Muehlenbeckia axillaris* forms extensive circular patches; the creeping fern *Blechnum penna marina*, its leaves thick and stunted, forms considerable colonies; the vegetation gets closer and typical steppe is installed.

On the other hand, the vegetation may develop otherwise, and the stable but quite stony ground be occupied by a shrub steppe of almost pure *Discaria toumatou*, a more or less leafless divaricating shrub 90 cm. to 1·5 m., or more, tall, furnished with abundant assimilating spines. At a distance such shrub steppe is black in colour and is an invariable sign of fan or of old river-bed. Between the shrubs there are frequently more or less tussocks.

(*c*.) River-bed.

The procession of events on river-bed is much the same as on fan, and the climax association will be tussock steppe or shrub steppe (*Discaria*), or, in the west, modified subalpine scrub. The most important pioneer plant of western river-bed is *Raoulia Haastii*, which builds true cushions of considerable diameter, green in colour, full of raw humus within, and which can cover not merely the smaller stones, but even enwrap such as

are 60 cm. tall A detailed account of the ecological history of a western subalpine river-bed by Cockayne will shortly appear in the "Transactions of the Botanical Society of Edinburgh," so little more need be said here.

Eastern river-bed vegetation commences with the same *Raoulia* species as eastern fan, and the procession of events is very similar, while it is obvious that the tussock steppe of a river-terrace summit has gone through the same changes as are happening on river-bed at the present time.

The old bed of the Ashburton near Hakatere is occupied by an extremely xerophytic subassociation, which would repay detailed investigation. Tussocks are few in number and far apart. The vegetation is quite open. The substratum is flat, very stony, and with but little fine soil. The xerophytic whitish moss *Racomitrium lanuginosum* is abundant, growing between the stones. There are many broad patches of the narrow erect flat green leafless stems of *Carmichaelia uniflora* and *C. Enysii.* Low silvery circular cushions of *Raoulia lutescens* are abundant. *Discaria toumatou* and *Helichrysum depressum*, no longer erect, are flattened to the ground. *Coprosma Petriei* (close turf-making subshrub with stout creeping stems and very small linear-oblong coriaceous leaves), *Wahlenbergia saxicola* (mat-forming, creeping, and rooting herb with small thick coriaceous leaves in open rosettes), *Acaena inermis* (mat-forming, creeping, and rooting subshrub with wiry stems and rather thin glaucous or reddish pinnate leaves in open rosettes), some green cushions of *Raoulia Haastii*, and a few flat or raised silvery round patches of *R. australis.* There are doubtless other species present. The subassociation occupies a wide area. It probably owes its structure and character not only to the edaphic conditions, but to the wind-swept habitat. An epharmonically similar subassociation occurs on the most stony ground of the Canterbury Plain, but the *Carmichaelia* is *C. nana* and the principal *Raoulia* is *R. Monroi.*

(*d.*) Tussock Steppe.

* *General.*

Montane and subalpine tussock steppe is merely a continuation of the same formation of the lowlands, and extends over much of the mountain area on the east of the Southern Alps, and has a fairly uniform floristic composition throughout. Tussock steppe is economically far and away the most important indigenous plant formation of the Dominion, and a thorough knowledge of its ecology is distinctly a matter of national importance. This statement is emphasized by the fact that overstocking and burning have so modified the original tussock steppe in various parts of the South Island that the value as pasture land is gone, a true desert having replaced the original grass land (see Cockayne, A. H., 1910).

** *Growth-forms.*

There are doubtless considerably more species in the association than given in our list, but a consideration of those contained therein should be quite sufficient to give a clear idea as to the growth-forms and their relative abundance.

The number of species noted is 103, of which 15 are *shrubs*, 12 *subshrubs*, and 76 *herbs.*

The shrubs are: *Evergreen*, 10; *deciduous*, 2, and *leafless*, 3. The following growth-forms are represented: The *creeping and rooting*, 9, of which 2 are *the flat-stemmed leafless; the prostrate non-rooting*, 2; *the divaricating*, 2, of which 1 is spiny; *the bushy*, 1; the *tall flat-stemmed leafless*, 1.

The subshrubs are: *Evergreen*, 9; *summer-green*, 3. The following growth-forms are represented: *Creeping (rooting)*, 11, comprising *turf-making* 2 and *leafless* 1; *erect*, 1.

The herbs are: *Evergreen*, 72; *summer-green*, 4. The growth-forms are represented by *annuals and biennials*, 4, made up of *erect and branching*, 3; *rosette*, 1: and *perennials*, 68, of which 4 are *summer-green*, made up of the following growth-forms—*tussock*, 6; *tufted grass*, 12, *creeping and rooting*, 24, of which 7 are *turf-formers*; *rosette*, 18, 2 of which are of the *Yucca form*; *prostrate not rooting*, 3; *cushion*, 3, but some of the creeping may assume this form; *erect and branching*, 2.

If the leaves of all the plants are considered it will be found that those of 17 species are very small, 14 have margins incurved or recurved, and 4 are leafless. Larger leaves are frequently stiff, thick or coriaceous, or flattened to the ground as rosettes. The number of glabrous leaves (70) is larger than might be expected, but these are frequently more or less coriaceous; tomentose leaves number 13.

Just as the steppe develops in connection with increasingly mesophytic edaphic conditions, so does the combination of growth-forms become gradually more mesophytic. But the freely developed steppe itself provides an altogether different environment to the unoccupied wind-swept ground, and it is the taller members of the formation alone (*tussock-grass*, *Yucca form*, *xeromorphic shrubs*) or the plants of special stony wind-swept ground (*dwarf leafless flat-stemmed shrubs*, *leafless summer-green subshrub*, *cushion and patch plants*, *turf-making creeping herbs*) that are exposed to severe conditions. Tall plants without very special adaptations cannot establish themselves, and about 80 per cent. of the florula consists of dwarf plants, mostly prostrate or creeping, which grow under conditions of considerable shelter.

*** *Physiognomy.*

The tussock steppe of the Arrowsmith district is no longer a virgin formation. Burning and overstocking have brought about a more xerophytic environment, and, although probably all the original species are present, their relative proportion is much changed, the originally dominant tussock having decreased together with the mesophytic grasses and herbs which grew in its shelter, while various xeromorphs (species of *Raoulia*, tomentose rosette plants, &c.) have increased and certain introduced plants have gained a footing.

Seen from a distance, tussock steppe appears as a smooth brown carpet on the dimpled hillside. A closer view dispels the illusion and reveals the bunched-up grass culms and leaves, close together at the round base of the tussock but spreading above and mostly dead at the apices, growing side by side, each some 40 cm. tall, in some places their leaves intermingling, and in others distant and with partially covered and more or less eroded ground between the clumps. Here and there stand above the tussock low dark-coloured bushes of *Discaria toumatou*. On the ground between the tussocks there are the creeping plants forming mats—glaucous of *Acaena Sanguisorbae* var. *pilosa*, reddish of *A. inermis*, brown of *Styphelia Fraseri*, pale whitish-green of *Raoulia subsericea*, green of *Brachycome Sinclairii*—orange-coloured small cushions of *Scleranthus biflorus* and great green semi-cushions or high circular mats of *Celmisia spectabilis*, rosettes flattened to the ground of *Senecio bellidioides* (dark green and hairy), *Craspedia uniflora* var. (whitish or greyish-green), the small round leaves of *Hydrocotyle novae-zealandiae* flattened to the ground, and round patches of *Muehlenbeckia axillaris* its

stems creeping beneath the surface. Other plants are quite common e.g., small tussocks of *Poa Colensoi*, tufted *Danthonia semiannularis*, *Carex breviculmis*, *Uncinia rubra*, *Colobanthus Billardieri* in tiny rosettes which may make small cushions, *Ranunculus multiscapus*, *Geranium sessiliflorum*, *Pimelea laevigata* var. *repens*, *Epilobium elegans*, the great bayonets of *Aciphylla Colensoi* (much less common than formerly), *A. squarrosa*, *Anisotome aromatica*, *Gaultheria antipoda* var. *depressa*, close turf of *Coprosma Petriei* on stony ground making in places a special "group," and in the most exposed and dry stations yellowish-green cushion 5 cm. in diameter of *Colobanthus brevisepalus*, *Wahlenbergia saxicola*, *Lagenophora petiolata*, *Celmisia longifolia*, *Vittadinia australis*, *Helichrysum bellidioides*, *H. filicaule*, *Cotula squalida*, *Microseris Forsteri*, and *Taraxacum glabratum*.

Its Subassociations.

† *Danthonia Raoulii* Steppe.

This subassociation frequently occupies wide areas. Its presence appears to depend upon increase of altitude, poverty of soil, acid or cold soil, and perhaps exposure to wind; but the conditions governing its distribution throughout New Zealand have been altogether insufficiently studied. The tussock itself is much taller than that of *Poa caespitosa* or *Festuca rubra* var. It is also much less relished by stock, and so its present distribution may not be a natural one.

†† *Danthonia flavescens* Steppe.

This subassociation generally occupies a higher altitude than *D. Raoulii* or *Poa caespitosa* steppe. Certain of the higher mountain plants enter into the combination, and the subassociation itself may grade off into fell-field. The dominant species is much relished by sheep, so the true ecology of the subassociation is not easy to determine.

††† Dwarf *Carmichaelia* Steppe.

This has been already described. Besides *C. Enysii* and *C. uniflora*, *C. nana* is in some places an important member, and the much stouter *C. Monroi* builds stiff open cushions, its stout woody root descending deeply and its short stiff stems more or less vertical. The low-growing *Veronica pimeleoides* var. *minor* grows here and there, a species with small glaucous leaves and blue flowers—a most unusual colour in New Zealand; and the leafless grey stems of *Muehlenbeckia ephedroides* may lie upon the stony ground, their very much stouter creeping stem hidden beneath the stones.

†††† *Triodia* Steppe.

This subassociation consists principally of an extremely dense turf of the small grass *Triodia exigua*, which spreads most extensively by means of its long much-branching rhizomes, which form eventually a matted tangle. The leaves are very narrow, 2·5 cm. long more or less, filiform, convolute, stiff, and almost pungent. *Styphelia Fraseri* grows through the turf, hugging the ground. *Carmichaelia Enysii*, *C. nana*, and *Stackhousia minima* are, so far as we remember, members of the combination, but unfortunately our notes are too brief for an accurate, detailed description.

(e.) *Gaya ribifolia* Association.

On fairly sheltered hillsides, in gullies, on river-terraces, and frequently where the ground is quite stony, especially in the lower Ashburton Gorge,

the monotony of the tussock is relieved by green clumps of trees. These consist of *Gaya ribifolia*, a low tree 6 m. tall, more or less. A few ferns may grow beneath the trees—*e.g.*, *Blechnum penna marina*, *Hypolepis millefolium*, *Polystichum vestitum*, and on the outskirts a few divaricating shrubs.

The presence of *Gaya ribifolia* is a sign of steppe climate, since a forest climate at once replaces it with the closely allied *G. Lyallii*. Both are strictly deciduous, but differ ecologically in their leaves, those of *G. ribifolia*, covered with hairs, being more xerophytic than the almost glabrous adult leaves of *G. Lyallii*. Both species pass through a somewhat similar persistent juvenile stage of development.

(*f*.) *Nothofagus cliffortioides* Forest.

N. cliffortioides forest may be considered the climax association of the subalpine-steppe climate. It occurs very sparingly in the Arrowsmith district, and is confined to a few gullies, or there may be merely a few trees, scattered or in clumps on the banks of streams.

N. cliffortioides is a low canopy tree with a close head of small stiff leaves. The branching is distichous, and the foliage consequently lies in layers. The trees are probably not very long-lived, and fall before the wind as they decay, their place being taken by a close growth of saplings, which, as seedlings, formed most of the undergrowth.

The following were noted as forming the undergrowth: *Blechnum penna marina* (creeping fern), *B. capense* (tufted fern), *Hypolepis millefolium* (summer-green creeping fern), *Podocarpus nivalis* (prostrate rooting shrub), *Aristotelia fruticosa*, *Coprosma propinqua*, *C. parviflora* (divaricating-shrub form), *Griselinia littoralis* (bushy shrub), *Fuchsia excorticata* (small deciduous tree), *Urtica incisa* (erect herb). Doubtless a number of other species are present, but at the best this association has few members. *Elytranthe flavida* (hemi-parasite) grows on the *Nothofagus*.

At one period, as also in Central Otago and elsewhere, as already noted by Speight, where now a steppe climate prevails there must have been extensive totara forests, for remains of trees lying on the ground have been frequently noted, as, for example, in the Cameron Valley according to Mr. L. Wood (see also Monro, 1869; Buchanan, 1869).

If such a forest existed, and occupied a wide area in the eastern subalpine and montane belts of the South Island, it seems almost impossible that it could have been altogether destroyed by fire, as popular and even scientific opinion has declared (see Monro, 1869; Buchanan, 1869). The only feasible explanation, then, is that put forth by Speight—that the climate not very long ago, geologically speaking, was more mesophytic than at the present time. If the Rakaia Valley be alone considered, it is almost certain an advance of the average western rain-line a few miles to the east would be followed by an advance of the present totara forest, and, although extending no further, it would persist for a long time after the climate had become xerophytic. On the other hand, a rainfall similar to that of the western Rakaia has only brought *Nothofagus cliffortioides* forest in the western Waimakariri district.

(*g*.) Lake, Swamp, Bog, &c.

The above series of associations are dealt with in this place because the climax association of a lake captured by vegetation is steppe, though

the process is a slow one, which, however, may be much accelerated by a stream depositing shingle, &c., on the lake-floor.

* *Lake.*

The most important lake is Lake Heron, situated at about 670 m. above sea-level. There are several smaller lakes on the Upper Ashburton Plain, also tarns on spurs which were formerly overridden by the ice, as well as small ponds in various places.

We have no details as to the lake-vegetation beyond the facts that *Typha angustifolia* var. forms the innermost girdle in some parts, and that towards the southern extremity of Lake Heron there is an extensive colony of niggerhead, probably *Carex secta*, with tall and stout trunks.

** *Swamp.*

On both sides of the so-called Lake Stream near where it issues from Lake Heron, and in certain places near the margin of the lake itself, there are extensive swamps which merge into bog and this into steppe. The water-content varies much at different seasons of the year, as likewise at times of heavy rain. Furthermore, their ecology has been much modified by burning and the trampling of stock.

Two principal subassociations were noted according to depth of the surface water—viz., *Schoenus pauciflorus* (deepest water), *Carex ternaria* (shallower water).

At a distance the swamp appears of a uniform grey colour. It is traversed by various streams, and pools of water lie permanently in many places. A close view shows that the grasslike *Carex Gaudichaudiana* is the most abundant plant. The two subassociations differ in colour, *Schoenus pauciflorus* being reddish and *Carex ternaria* green. On the surface of pools there is abundance of *Ranunculus rivularis*, which may quite hide the water. *Montia fontana*, a species of *Myriophyllum*, and *Epilobium macropus* occur more or less abundantly in the streams. *Schizeilema nitens* (creeping and rooting slender-stemmed herb with small trifoliate shining glabrous leaves) is abundant where water lies and the light is sufficient.

Epilobium insulare, *Carex diandra*, *C. stellulata*, *C. Oederi* var. *cataractae*, and *Elaeocharis Cunninghamii* are common on the very wet ground.

As the soil gets drier *Mazus radicans*, its thin spotted yellowish leaves flattened to the ground, is abundant, and both *Carex ternaria* and *Schoenus pauciflorus* are absent. Drier soil still favours the presence of *Pratia angulata*, and probably *Isotoma fluviatilis*, a creeping herb of similar growth-form, is present. The following are other plants of the boggy ground: *Utricularia monanthos*, *Plantago triandra* (rosette plant), *Asperula perpusilla*, a species of *Cotula*, *Viola Cunninghamii*, *Luzula* species (flat, red leaves).

Finally, *Bulbinella Hookeri* var. *angustifolia* (summer-green herb with tuberous roots) is common both on wet and on dry ground, forming most noticeable colonies when in bloom with its bright-yellow flowers, but it is absent in the wettest part of the swamp. Also, this plant is extremely common in wet ground throughout the montane and subalpine belts of the district, and increases enormously after the vegetation is burnt.

*** Sphagnum *Bog.*

Only the bog connected with steppe is here dealt with; that of the forest climate, and which elsewhere in New Zealand is related to fell-field and moor, was not examined.

Bog surrounded by steppe can be seen at various stages of development. In one place on Prospect Hill (about 900 m. altitude) the hollow clearly indicates a former tarn in a rock-basin, but the whole is now *Sphagnum* bog, while in another place, close by, a tarn is in course of occupation by bog. Let us first consider the tarn.

This, where it joins the bog, is about 30 cm. deep. The water, then, will get quite warm on a hot summer's day. Growing in it is *Elaeocharis Cunninghamii?* (slender rush form), *Carex ternaria* (grasslike sedge), and the *Sphagnum* moss grows out into the water, its margin unevenly undulating. With the advancing moss there is *Schizeilema nitens* and tussocks of *Schoenus pauciflorus*, the former also floating on the water just at the edge of the tarn. *Drosera arcturi* (small herb with short rootstock and reddish linear-ligulate leaves furnished above with glandular hairs) and *Carex stellulata* are amongst the first plants to settle on the *Sphagnum*. Tussocks of *Danthonia Raoulii* also come occasionally right to the front. The grassy and far-spreading *Carex Gaudichaudiana* is abundant, but it is a later arrival than any of the above. Other plants are *Oreobolus pectinatus* (dense small green cushions of distichous stiff short linear-subulate leaves with broad equitant bases), *Carex subdola*, *Pratia angulata*. *Drosera arcturi* and *Carex stellulata* are very abundant all over the bog, but there is much less tussock than on the older bog to be next described.

The bog which has buried the tarn is made up of close masses of *Sphagnum*, which for the most part is concealed by the grassy *Carex Gaudichaudiana*. In many parts steppe is virtually installed, as tussocks of *Danthonia Raoulii* are dominant. Where these do not touch there are open spaces occupied by *C. Gaudichaudiana*, *Bulbinella Hookeri* var. *angustifolia*, *Blechnum penna marina*, some tussocks of *Poa caespitosa*, *Anisotome aromatica*, creeping *Gaultheria depressa*, a species of *Polytrichum*, *Viola Cunninghamii*, *Schizeilema nitens* and *Ranunculus rivularis* (where water lies), *Celmisia longifolia*, *Epilobium chloraefolium*, *Helichrysum bellidioides*, *Wahlenbergia saxicola*. Here and there, right on the *Sphagnum* cushions, are rounded low bushes of *Dacrydium Bidwillii*. As is well known, the *Sphagnum* plants die below and are gradually converted into peat, while their apices continue to grow upwards; and if the plants which have settled upon the moss are not able to grow upwards at the same rate as the bog, rooting at the same time, they will be eventually buried by the moss and killed. Thus on this particular bog plants of the dwarf taxad, *Dacrydium Bidwillii*, exhibit various stages of burial, notwithstanding the power this shrub has of extending by means of creeping and rooting prostrate stems furnished with spreading juvenile leaves. On the other hand, the rhizomatous sedge, *Carex Gaudichaudiana*, can grow faster than the moss, form a turf, and check its upward growth altogether; so that the moss in its turn is the vanquished. With the consequent drying of the ground, steppe is by degrees established, but it must be understood that the first-coming tussocks on the bog-moss are liable to burial, and a growth of these does not of necessity denote the installation of steppe.

† Growth-forms of Bog.

The following growth-forms were noted on the bogs of the district:—

The number of species in the list of plants is 36 (35 evergreen, 1 summergreen). This would have been greater most undoubtedly had we reached the bogs (1,200 m. altitude) on Mein's Knob.

The growth-forms are as follows:—

Shrubs: Creeping and rooting, 2, of which 1 is *prostrate with subterranean stem* and 1 *bushy* and 60 cm. or so tall.

Herbs: Creeping and rooting, 21, of which 5 are *grasslike*, 1 *rushlike*, 2 frequently *aquatic with floating leaves*; *rosette form*, 5; *erect*, 3, of which 1 is *grasslike*; *tussock*, 3, of which 1 is *rushlike* (slender); *cushion form*, 1; *prostrate non-rooting*, 1.

At least 70 per cent. of the species are also plants of steppe or other dry habitats.

Bog at a higher altitude, or exposed to greater snowfall—*i.e.*, to colder water—on an average is more xerophytic, and contains especially a higher percentage of cushion plants.

Also, pure *Sphagnum* cushions in vigorous growth, thanks to the non-acid rain-water absorbed by the upper surface, will allow mesophytes to settle down which cannot tolerate acid peat (see Cockayne, 1910, p. 111).

(β.) ROCK FELL-FIELD SERIES.

(1.) *General.*

The altitude of the upper line of the steppe is very variable, but probably corresponds to a large extent with the line of the ancient valley glacier. It also constitutes the lower limit of the series of plant-associations under consideration, which depends in large measure upon the presence of an easily disintegrated rock, though it is governed to no small degree by altitude and climate.

Under the influence of frost the much-jointed sandstones, greywackes, and slates become rapidly disintegrated, the stone-fragments (too great in quantity to be removed by rain) accumulate to such an extent that great fields of *débris* occupy almost the entire mountain-surfaces for hundreds of metres. Here and there jagged masses of much-corroded rock jut out from the stone-fields and break the uniformity of the long grey even slopes. Gullies with more or less precipitous walls seam the mountain-sides, a stream sometimes occupying their floors, the water issuing all on a sudden from the base of a great stone-field at the head of the gully, and perhaps as suddenly disappearing lower down beneath the ever-increasing mass of loose stones. From the above it is plain that the edaphic conditions of the upper subalpine and alpine belts are those of desert, and it is plain also that increase of altitude, irrigation by snow-water, strong insolation, high winds, and occasional droughts help to increase the xerophytic character of the plant-habitats during the vegetative period.

Altitude and the average height of the winter snow-line, above which the snow lies from four to six months,‡ separates the area into alpine and subalpine belts.

The three following plant-formations occur, arranged in order of succession: *Rock, shingle-slip, fell-field.*

(2.) *The Associations.*

(*a*.) Rock.

The following are the only special rock-plants: *Hymenophyllum villosum* (filmy fern), *Polypodium pumilum* (very small fern with tufted leaves),

‡ This is undoubtedly the outside limit.

Trisetum subspicatum (small tufted pubescent grass), *Cardamine depressa* (small rosette herb), *Colobanthus acicularis* (small cushions of rigid glabrous linear-subulate acicular leaves), *Hectorella caespitosa* (dense cushions of small imbricated coriaceous leaves and thick root), *Pimelea Traversii* (small shrub with tortuous branches and short thick glabrous imbricating leaves), *Celmisia bellidioides* (subshrub forming loose cushion of leaves in rosettes), *Raoulia eximia* (very large dense tomentose-leaved cushion plant with woody main stems and stout woody deeply descending root), *Helichrysum grandiceps* (short-stemmed subshrub with small imbricating silvery tomentose leaves), *H. microphyllum* and *H. Selago* (tomentose cupressoid shrubs, more or less of cushion habit).

Also, the following are common rock-plants, though not absolutely confined to rocks: *Luzula pumila* (small cushion), *Veronica pinguifolia* (decumbent low shrub with thick glaucous leaves), *V. tetrasticha* (dwarf cupressoid shrub), *V. epacridea* (decumbent shrub with imbricating thick recurved concave leaves).

The rock-vegetation is scanty. It is most abundant on the shaded parts. The true rock-plants are chasmophytes. Where there are deep chinks and ledges peat forms, and then various plants of the fell-field occur —*e.g.*, *Ranunculus Monroi* var. *dentatus*, *Anisotome aromatica*, *Aciphylla Monroi*, *Gaultheria rupestris*, *Dracophyllum rosmarinifolium*, *Helichrysum bellidioides*, *Celmisia spectabilis*, and sheets of *Hymenophyllum multifidum* (hardly a fell-field plant on a dry mountain).

So far as the true rock-plants are concerned, they are a category by themselves, and have no relation to fell-field vegetation, but the remainder can play their part in populating stone-fields.

Vegetable-sheep Subassociation.

Where the rock is almost weathered away, and stands raised here and there as a small island in the stony desert, it is frequently occupied by the great cushions of *Raoulia eximia* 1 m. or more in diameter. This most curious shrub has exactly the same growth-form as its herbaceous relatives of the river-beds. There is a central main stem and a few primary woody branches radiating therefrom which branch repeatedly, the secondary branches and those which follow having a tendency to grow upwards, and this is assisted by the frequent branching and consequently increasing density preventing their otherwise horizontal extension. The closeness of growth, through cutting off the light, causes the death of all the interior leaves and many of the stems, so that only the stouter remain, the interspaces becoming filled closely with a sticky raw humus into which the ultimate branches send abundant roots. The only living leaves are those pressed closely to the shoot-axis for a few centimetres near the apices of the ultimate branches; they are narrow-obovate, 3 cm. or so long, and densely covered near their apices with white hairs which stand almost erect. The shrub as a whole forms a great hard cushion, the ultimate shoots being pressed together as closely as possible. The interior peat even in the driest weather is soaking with water, and it is probable that the plant gets its chief food and water supply from this source, the main root, sent far into the rock, serving principally as an anchor.

Certain of the fell-field plants may grow upon the cushions, thanks to the wet raw humus contained therein.

(b.) Shingle-slip.

* General.

The edaphic distinction between shingle-slip and fell-field lies in the fact that the former consists altogether of loose stones lying at so steep a slope that those of the uppermost layer move downwards from time to time, whereas the stones of the fell-field are in a much more stable position, and there is generally a considerable percentage of true soil. This instability of shingle-slip has led to the occupation of this land-form not merely by certain growth-forms, but actually by distinct species *which do not occur in any other formation.* Furthermore, the plants are distant so far from one another, and the general plant covering is so scanty, that it plays no part worth mentioning in adding humus to the soil, while the formation is distinct in itself and has nothing to do with the installation of fell-field. It is, in fact, a definite vegetation entity whose life-history it is now impossible to examine, and whose origin is wrapped in obscurity.

The shingle-slip species are confined to the South Island,‡ and the majority to the drier mountains of the east. The following is a list of those found in the Arrowsmith district in its widest sense: *Stellaria Roughii* (Caryophyll.); *Ranunculus Haastii*, *R. crithmifolius*, *R. chordorhizos* (Ranunc.); *Notothlaspi rosulatum* (Crucif.); *Acaena glabra* (Rosac.); *Swainsona novae-zealandiae* (Legum.); *Epilobium pycnostachyum* (Onagrac.); *Anisotome carnosula* (Umbell.); *Myosotis Traversii* (Borag.); *Lobelia Roughii* (Campan.); *Veronica Haastii* (Scrophular.); *Haastia Sinclairii*, *Craspedia alpina*, *Cotula atrata* (Compos.).

The following are also frequent members, but are not confined to shingle-slip: *Claytonia australasica* (Portulac.), *Anisotome filifolia* (Umbell.), *Veronica tetrasticha*, *V. lycopodioides*, *V. epacridea* (Scrophular.).

** Growth-forms.

The shingle-slip plants afford a most admirable example of convergent epharmony. Nearly all are summer-green low-growing or prostrate herbs, with the leaves more or less in rosettes, though these are frequently masked through the stems, which have the power of lengthening as buried, being covered with *débris*. The leaves of almost all are fleshy or coriaceous, glabrous, glaucous, and almost the colour of the stones, and in some cases very deeply divided, the bending-together of the final segments much reducing the leaf-surface. *Haastia Sinclairii* and *Craspedia alpina* are densely woolly, the latter, clothed with long snow-white wool, being especially noticeable. The species of *Ranunculus* and *Anisotome carnosula* have stout fleshy rhizomes; *Lobelia Roughii* and *Swainsona* slender but far-spreading much-branching stems creeping amongst the stones. *Notothlaspi rosulatum* is annual or biennial.

The texture of leaves and stems is such as to withstand the blows of sliding stones, and the plants as a whole can grow upwards, as buried, after the manner somewhat of dune-plants, though, of course, to a much lesser degree.

*** Ecological Conditions.

† Edaphic.

The soil consists of loose angular fragments of stone, frequently quite small, lying upon one another, and the slope of the surface is so steep that

‡ *Veronica spathulata* of scoria slopes in the central volcanic plateau has a shingle-slip form.

the stones are very liable to move downwards, considerable breadths of the uppermost layer frequently slipping *en masse.* In some places there is little finer soil, but generally there is a good deal of sandy *débris*, and not infrequently a certain amount of sandy clay, especially at some distance below the surface, where the ground is more stable.

Although the stones are quite dry on the surface, at a depth of a few centimetres they are damp, and lower still there is ample moisture available for deep-rooting plants.

Movement of the stones, the most important distinguishing feature of the soil from that of fell-field, is much less near the sides of the shingle-slip than elsewhere, and there sufficient stability is provided for plants other than those of the true shingle-slip formation to settle down.

The looseness of the surface acts as a " dry mulch " and prevents evaporation from below.

†† Climatic.

The general climate is, of course, that of the district and the altitudinal belt. The special climate depends upon lack of shelter, and consequently great exposure to wind ; strong radiation of heat from the stones ; powerful heating of the stones themselves; and occasionally very bright light. Within the space of a few hours the plants are frequently subjected first to a burning heat and then to considerable frost ; one hour they may be surrounded by a moist atmosphere and the next exposed to a strong dry wind. In winter they are covered by snow for four months or more, but this covering is of little moment to the summer-green herbs. Shortly after the snow has melted the leaves appear above the stones, and even by the beginning of November *Veronica epacridea* may be in bloom.

(c.) Fell-field.

** General.*

Warming's description of fell-field (1909, p. 256) might have been written on a New Zealand dry mountain : " The soil is never completely covered by plants. One individual stands here, and another there ; between them we see bare, stony, sandy or clayey soil, which is devoid of humus and determines the prevailing colour of the landscape." An English name was much needed for this formation, previously called by Cockayne " alpine meadow " (1900, p. 128), and a combination of " fell " — a barren or stony hill, and " field " a wide expanse, chosen by Groom as the English equivalent of " fjeldmark," seems to us to meet the case.

Fell-field is poorly developed in many parts of the Arrowsmith district, and forms patches or lines, oasis-like, in the desert of unstable stones. It commences by a few plants settling on the stable margin of the shingle-slip or where the stone-field happens to be flat, and as soil is slowly formed so do the species increase in number, but never make here a closed formation. At its lowest limit steppe and fell-field merge into one another, and are not distinguishable ; even to quite a high altitude occasional tussocks of *Danthonia flavescens* are present.

The following are amongst the earliest plants to occupy the stable *débris : Danthonia semiannularis* var. *setifolia*, *Acaena Sanguisorbae* var. *pilosa*, *Pimelea Lyallii*, *Epilobium* sp. (formerly merged with *E confertifolium*) *Hydrocotyle novae-zelandiae*, *Anisotome aromatica Gaultheria rupestris*, *Dracophyllum rosmarinifolium*, *D. uniflorum*, *Pratia macrodon*, *Phyllachne Colensoi*, *Forstera Bidwillii Brachycome Sinclairii*, *Celmisia discolor*, *C. spectabilis*, *Helichrysum bellidioides*, and *Cotula pyrethrifolia*.

Celmisia viscosa, *Veronica pulvinaris*, *Luzula pumila*, and *Phyllachne Colensoi* are virtually confined to the alpine belt.

** *Growth-forms.*

Our list of eastern fell-field plants is too meagre to warrant a detailed inquiry into the growth-forms, and such would be misleading. Suffice it to say that there are represented *creeping and rooting shrubs, subshrubs and herbs, herbs and subshrubs of the cushion form, rosette plants*, and *tussock-grasses*, while xerophytic structure of many kinds is exhibited.

(C.) Forest-climate Formations.

(α.) General.

The very much greater rainfall and the increase in number of rainy days lead to a more rapid growth and speedy establishment of species, together with a much closer plant covering, than does the steppe climate. Likewise there are much more extensive formations of trees and shrubs. The formation and accumulation of raw humus is strongly favoured—so much so, indeed, that even rocks may be covered with a true soil, and bear a fairly dense and rich plant covering. On the other hand, the winter snowfall is greater, and the proximity of permanent snowfields and glaciers are counteracting factors.

(β.) The Rock-forest Series.

(1.) *General.*

The sequence of events in the succession of the plant-associations in the Upper Rakaia Valley can be well seen on the northern bank of the river, taking the mouth of the River Louper as a central point.‡

Thus, "Bare rock is the first. Its disintegration leads to shingle-slip, on which special shingle-slip plants, or those of rock or fell-field possessing suitable adaptations, can settle. These prepare the way for fell-field, and this in its turn may give place to forest by way of scrub at the lowest altitude.

"At the same time reversion frequently occurs, and there are excellent examples to be seen where forest has been destroyed by a shingle-stream. Recolonizing ensues, the plants coming from those close at hand. On the south side of the river the process is also in progress. Here a descending stream of stones has cut a path through the forest. Shingle-slip plants come first, then a grassy fell-field, which is replaced by shrubs, and these, at a suitable elevation, by forest."

(2.) *The Associations.*

(a.) Rock.

Although plenty of the alpine rocks bear an abundant plant covering, this does not betoken a pioneer association, but is much younger than a good deal of the vegetation adjoining, many of the species depending on the peaty soil and having probably come by way of the fell-field.

The rocks examined were at an altitude of from 1,280 m. to 1,390 m. They were covered in places with a good deal of raw humus. The species noted

‡ What follows is almost word for word from notes written by Cockayne on the spot.

were: *Gaultheria rupestris* (small erect thick-leaved shrub), *Dracophyllum Kirkii* (small prostrate shrub with stiff coriaceous crowded leaves), *Helichrysum grandiceps* (subshrub more or less erect, leaves small, imbricating, silvery, tomentose), *Senecio Bidwillii* (stiff-branched shrub with very thick leaves tomentose beneath), *Coprosma serrulata* (shrub creeping beneath the surface and rooting, its leaves moderate-sized and stiff)—the above may be called rock-plants, though all occur elsewhere; *Danthonia flavescens*, *Ranunculus Lyallii*, *Anisotome Haastii*, *A. pilifera*, *Aciphylla Colensoi* var. *maxima*, *Dracophyllum Urvilleanum* var. *montanum*, *Coprosma cuneata*, *Celmisia Sinclairii*, *C. coriacea*, *C. petiolata*—all of which are plants of the fell-field.

(*b.*) Shingle-slip.

The most important shingle-slips are those which descend to the valley glaciers, and where alone succession can be accurately investigated, but owing to various causes there was no opportunity for examining such.

The only shingle-slip studied consisted of rather large stones, and was much more stable than those already described for the steppe climate.

The earliest plants to occupy the stony ground appear to be *Epilobium pycnostachyum*,‡ *E. melanocaulon* (at the lowest altitude), *E. glabellum*, *Muehlenbeckia axillaris*, *Helichrysum bellidioides*, *Veronica Bidwillii*, *Senecio lautus* var. *montanus*, *Raoulia tenuicaulis*—a combination very similar to that of river-bed, since the stability of the slip renders the station very similar.

Very soon the grass *Poa anceps* var. makes its appearance, and forms a deep carpet, quite hiding the stones, and by the great amount of dead matter it produces makes much soil and encourages various fell-field plants to settle down. Shrubs invade the shingle-slip, and capture not only the grass but even the stable stones, and herbaceous plants come in early, especially *Hypolepis millefolium*, *Viola Cunninghamii*, and *Geranium microphyllum*, so that scrub or fell-field, as the case may be, is established.

(*c.*) Fell-field.

* *Species, &c.*

The plants are fairly close, in some places growing into one another. Tussocks of *Danthonia flavescens* are dotted about, as also clumps of *Phormium Cookianum* and low rounded green bushes of *Veronica subalpina*. *Ranunculus Lyallii* forms large colonies, its massive rhizomes hardly below the surface, and its great glossy green peltate leaves raised on stout petioles 30 cm. or often more in height. There are tall *Yucca*-like plants of *Aciphylla Colensoi* var. *maxima*. The following herbaceous plants of considerable dimensions are common: *Celmisia coriacea*, *Anisotome Haastii*, *Astelia montana*, *C. Sinclairii*, *Polystichum vestitum*. The stout low-growing shrubby stiff-leaved *Coprosma serrulata*, spreading by its underground stems, is abundant. Other plants belonging to the association are *Hypolepis millefolium*, *Trisetum Youngii*, *Hierochloe Fraseri*, *Poa anceps* var., *Viola Cunninghamii*, *Acaena Sanguisorbae* var., *Taraxacum glabratum*, *Senecio scorzoneroides*, *Coprosma ramulosa*, the shrub *Carmichaelia grandiflora* (often abundant), *Geranium microphyllum*, *Coriaria angustissima*.

‡ The only true shingle-slip species; but shingle-slip plants are virtually confined to mountains with a steppe climate.

At 1,390 m. altitude, where the ground is rocky, the erect needle-leaved shrub *Dracophyllum Urvilleanum* var. *montanum*, distinguished by its brown colour, is very plentiful, associated with tussocks of *Danthonia flavescens*, and mixed with them the large-leaved herbaceous plants, the whole making a closed association.

On some of the Rakaia fell-fields there are wide stretches of *Ranunculus Lyallii* mixed with *Ourisia macrocarpa*, and I suspect there would be also plenty of *Ranunculus Godleyanus*, but there was no opportunity of examining such a combination.

*** Growth-forms.*

The growth-forms of forest-climate fell-field differ from those of the steppe climate chiefly in the presence of a much more mesophytic element, with leaves sometimes of great size—*e.g.*, *Ranunculus Lyallii*, *Ourisia macrocarpa*, *Anisotome Haastii*, *Senecio scorzoneroides*. But xerophytes are not absent—*e.g.*, *Aciphylla Colensoi* var. *maxima*, *Phormium Cookianum*, *Astelia montana*, *Celmisia coriacea*, *C. Sinclairii*—though such as these are not to be compared with *Celmisia Lyallii*, *C. viscosa*, or *C. pseudo-Lyallii* of the drier fell-field, also large plants. At above 1,500 m. doubtless, as in fell-field in general, true xerophytes increase in numbers, but so high an altitude on the mountains of the forest climate was not reached.

(*d.*) Subalpine Scrub.

** General.*

It has been already seen that a good many shrubs are present on fell-field or rock. It is only necessary for certain conditions to prevail and the shrubs will get the ascendency and scrub be installed These conditions are probably an altitude of not more than about 1,200 m. (with which is connected a snow-covering of shorter duration than at a higher altitude), shelter from the more intense winds, a soil containing a considerable percentage of humus.

Subalpine scrub occurs on old river-terrace, moraine, slopes near the source of rivers, and as a belt on the hillsides, frequently between the upper margin of the forest and the fell-field.

The general character of subalpine scrub has been sufficiently described by various authors (see, *e.g.*, Haast, 1866; Green, 1883; Harper, 1896; Laing and Blackwell, 1907; Cockayne, 1906, 1909, 1910). That of the Rakaia, as Haast first pointed out (1866), is of a maximum density. The roof is fairly even; its dominating colour is green, but there are many patches of brown. Its height varies according to altitude and exposure, it being tallest on river-bed, in gullies, and at its lowest altitude. At 1,000 m. elevation it may average 1·8 m. The shrubs grow into one another, their stiff or rigid branches frequently stretch horizontally *down* the slope, the scrub as a whole being in places virtually impenetrable.

*** Composition.*

The following were the species noted: *Polystichum vestitum* (Fil.); *Podocarpus nivalis*, *Phyllocladus alpinus* (Taxac.); *Clematis australis* (Ranun.); *Carmichaelia grandiflora* (Legum.); *Aristotelia fruticosa* (Elaeocarpac.); *Gaya Lyallii* (Malv.); *Nothopanax simplex*, *N. parvum*, *N. Colensoi* (Araliac.); *Griselinia littoralis* (Cornac.); *Aciphylla Colensoi* var. *maxima* (Umbell.); *Archeria Traversii*, *Dracophyllum longifolium*, *D. Urvilleanum* var. *montanum* (Epacrid.); *Veronica salicifolia*, *V. subalpina* (Scroph.); *Coprosma serrulata*,

C. ciliata. C. parviflora. C. rugosa (Rubiac.); *Olearia nitida, O. macrodonta, O. ilicifolia, O. nummularifolia, Cassinia Vauvilliersii, Senecio cassinioides, S. elaeagnifolius* (Comp.).

*** *Growth-forms.*

The "normal" forms of scrub plants are much modified by the mechanical action of wind and snow, and it is to the dwarfing, the horizontal spread of branches, and, above all, the close intermingled growth that the scrub maintains its position rather than to any special growth-forms of the constituents. This is admirably shown by the forest-tree *Nothofagus cliffortioides*, which, like the ecologically equivalent *Pinus montana* of Europe, can assume a scrub form, and so make a special type of subalpine scrub, as in the Nelson mountains.

Regarding the Rakaia shrubs, all except two are *evergreen*. The *shrub-composite* form, the *divaricating form*, the *ball-like form*, the *creeping and rooting form*, the *bushy form*, the *Dracophyllum form*,‡ are all represented. Nearly all have stiff, coriaceous, or thick leaves. The leaves of six are tomentose; of two erect, needle-like, isolateral or nearly so; of nine quite small. In short, with the exception of the deciduous element, *Veronica salicifolia* and perhaps *V. subalpina*, the leaf-form and structure is xerophytic or subxerophytic. *Clematis australis* is a tendril-climber, with much-divided rather thick leaves. The other lianes occur in the scrub of the river-bed.

(*e.*) Subalpine Totara Forest.

An association in which the totara (*Podocarpus Hallii*, and perhaps *P. totara* also) is the dominant tall tree occupies the base of the mountain-slopes on both sides of the Rakaia Valley, extending on the sunny side to a higher altitude (perhaps 970 m.) than on the shady side. Only the forest on the southern side (sunny side) of the river was examined, it being impossible to ford the river on foot.

The formation is the same as that composing the upper forest of Westland extending from the Taramakau Valley to the River Paringa, but it differs considerably floristically.

The association under consideration changes considerably both floristically and ecologically according to altitude, the lower and upper portions constituting respectively two subassociations.

The lower forest contains the following species which are wanting (or rare) in the upper forest: *Asplenium flabellifolium, Carpodetus serratus, Pittosporum tenuifolium, Sophora microphylla, Fuchsia excorticata, Pseudopanax crassifolium.*

*† *Upper Forest (Totara-Kawaka Subassociation).*

† Character.

The upper forest (see Plate VII, fig. 1) is distinguished by the presence of *Libocedrus Bidwillii* (kawaka) as a tall tree, in addition to the totara; by the presence of certain members of the subalpine scrub, which, shrubs no longer, have now the form of small trees; and, above all, by the generally horizontal trunks of these latter. The floor is covered in most places with a tall growth of the fern *Polystichum vestitum*. Moss mantles are abundant on the horizontal trunks and branches.

‡ Naked stiff stems, often more or less fastigiate; leaves long, grasslike, in erect rosettes at the apices of the twigs, and frequently almost isolateral.

†† Composition.

Tall trees: *Podocarpus Hallii, Libocedrus Bidwillii.*

Moderate-sized and small trees: *Phyllocladus alpinus, Gaya Lyallii,*‡ *Griselinia littoralis, Suttonia divaricata, Veronica salicifolia, Coprosma linariifolia, Olearia ilicifolia, Senecio elaeagnifolius.*

Shrubs: *Polystichum vestitum, Phyllocladus alpinus, Gaya Lyallii, Aristotelia fruticosa, Suttonia divaricata, Coprosma ciliata, C. parviflora, C. cuneata, Veronica salicifolia.*

Lianes: *Rubus schmidelioides* var. *coloratus.*

Epiphytes: *Hymenophyllum sanguinolentum, Asplenium flaccidum, Lycopodium Billardieri, Senecio elaeagnifolius.*

Parasite: *Tupeia antarctica*, on *Gaya Lyallii.*

††† Physiognomy.

The forest is made up of three tiers—viz., the tall trees, their heads of foliage distant; the smaller trees, their heads closer, but the forest-roof as a whole open; the closely growing short-trunked layer of *Polystichum vestitum.* In addition to the above, especially where there is a maximum of light, there is a discontinuous tier of more or less straggling divaricating shrubs. On the ground where there is space there is abundance of seedlings of *Gaya Lyallii* and a few floor-plants—*e.g.*, *Asplenium Richardi, Epilobium linnaeoides, Hydrocotyle novae-zelandiae*, and *Uncinia uncinata.*

The leading physiognomic feature is the horizontal and semi-horizontal thick and most irregular trunks of the small trees, especially the composites (see Plate VII, fig. 2), with their long depending strips of papery bark, their naked branches, which finally branching several times, candelabra-like, form a spreading open greyish-coloured head.

The trunks are frequently much moss-covered, but, although there may be thick masses, these can hardly be called cushions, as compared with those of Westland, Stewart Island, &c.

†††† Ecology.

The soil consists, so far as it was examined, of an upper layer of loose humus some 12 cm. deep and full of roots, succeeded by stones (old shingle-slip), into which a good deal of the finer humus has penetrated. This upper layer holds and stores water, and the network of roots shows how important a part its power to do so plays in the economy of the forest, and how dependent this is on the frequent downpour—that it is, in fact, a true rain forest.

The general more or less horizontal habit of the composite trees and *Griselinia littoralis* is very striking, and doubtless to be correlated with the mechanical action of the wind, though certainly there must be an hereditary tendency to respond to the wind-stimulus, as Cockayne has already suggested from observations on seedlings (1904, p. 254). How greatly the ecology of a formation depends upon the formation itself—that is to say, how a formation when established brings a change in its own environment—is here illustrated by the remarkably luxuriant growth of so many of the components. Thus the usually densely divaricating shrub *Suttonia divaricata* becomes an erect tree at least 6 m. tall and 57 cm. in diameter, branching above into a small head of "weeping" slender twigs. *Coprosma linariifolia* measured in one instance 66 cm.§ in diameter at the base of its

‡ If a plant is mentioned under two heads it means that it has two growth-forms.
§ Kirk (1889, p. 187) gives 9 in. (22·9 cm.) as an extreme size.

Fig. 1.—View of Exterior of Totara Forest, Upper Rakaia.

Fig. 2.—Horizontal Trunk of *Olearia ilicifolia*.

Face p. 64.]

trunk. *Olearia ilicifolia* was noted as quite 12 m. tall, and its trunk 71 cm. in diameter, a truly remarkable size for a tree composite.

The behaviour of *Gaya Lyallii* within the forest is a matter of interest which still requires a satisfactory explanation, our remarks below notwithstanding. In none of the young plants examined, which grew upon the forest-floor, was the main stem at first erect; on the contrary, it was prostrate for many centimetres, putting down roots into the loose substratum. In nearly all the plants examined the apex of this creeping stem was damaged, but it put forth erect branches which ultimately, as examination of many plants at different stages proved, became the final trunk. Leaning trunks of *Gaya* put forth rapidly growing erect stems (suckers), which would finally resemble trunks. How far the floor of moist loose humus and semi-decayed leaves, which certainly would favour the production of adventitious roots, which by their pull would hold the shoot to the ground, is responsible for this primary creeping and rooting habit it is hard to say. Other shrubs of this association show the same phenomenon—*e.g.*, *Aristotelia fruticosa*, "normally" a dense divaricating shrub, an example of which was noted with the basal 4 cm. prostrate and rooting, then the succeeding 5 cm. raised from the ground but still almost horizontal and giving off two vertical branches, and finally 3·5 cm. bending upwards until erect. The cases already cited by Cockayne (1908) of *Styphelia fasciculata* and *Myrtus pedunculata*, both "normally" erect shrubs, but on the moist mossy floor of the subalpine forest of Ruapehu being creeping and rooting plants, not erect at all, are analagous examples.

The divaricating shrubs are not nearly so dense as in the open. *Coprosma parviflora*, for example, has in this forest several stems which are quite without branches for the lower two-thirds, when they arch downwards and branch abundantly, this growth-form reminding one of the usual mesophytic habit of *C. foetidissima*, plants generally quite dissimilar in form.

The moss-clad horizontal trunks favour the presence of epiphytes, *Senecio elaeagnifolius* especially following this manner of growth, and attaining a remarkable size. As the plant increases in bulk the moss no longer supplies enough water, and the roots lengthen, pass downward, and enter the soil. Finally such roots may grow together and make a trunk. Many of the trees of *Griselinia littoralis* and *Olearia ilicifolia* have also originated in this manner.

The two tall trees may both be considered xerophytes. Both can tolerate physiologically dry stations—*e.g.*, wet peaty soil; but *Podocarpus Hallii*—nor *P. totara*, for that matter—does not appear capable of enduring a steppe climate, or, in other words, they are not found at present under such xerophytic conditions as is *Nothofagus cliffortioides*. So far as form, leaf-structure, and so on, are concerned, there seems no reason why the totaras should differ in their requirements from the beech. Certainly the *Nothofagus* is more plastic; it can more readily change its form according to circumstances; it is on the borderland of the deciduous habit; and as a forest it has wonderful powers of rejuvenescence, thanks to the shade-tolerating power of its seedlings. The above would give it an advantage over *P. totara* or *P. Hallii*, but in addition, as in many other plants, there are physiological distinctions not recorded, or not yet estimated, in form or structure which determine the habitat-range of a species.

As for the totara forest of the Rakaia Valley as a whole, it is altogether more mesophytic than is the *N. cliffortioides* association, and must be classed with rain forest.

4. THE FLORISTIC BOTANY.

(A.) Notes on various Species.

The number of species noted (357) most certainly does not represent *nearly all* that must occur in an area so large and diversified, and future observers cannot fail to much extend the list. At the same time, it may be pointed out that the steppe, owing partly to its climate and partly to the constant grass-fires, is distinctly barren, while the adjacent subalpine and alpine belts consist chiefly of dry rock and shingle-slip, stations hostile to plant-life. Further, so far as that part of the district with a forest climate is concerned, only the sunny side of a small portion of the Rakaia Valley, the poorest in both flora and vegetation, was examined, while the examination was but a cursory one.

(1.) **Luzula ulophylla** (Buchen.) sp. nov. — *L. racemosa* Desv. var. *ulophylla* Buchen. in Oesterr. Bot. Zeitschrift, p. 245, 1898.

An excellent description is given in Cheeseman's Manual, p. 738. The plant can be recognized at a glance, and certainly is one of the most distinct forms of the genus in New Zealand, as Cheeseman has already pointed out.

(2.) **Bulbinella Hookeri** (Col.) Benth. and Hook. f., var. **angustifolia** var. nov.

In omnibus partibus typo minor, non autem glaucis, superiore superficie folii concava, racemo quam typi breviore, densioreque.

South Island: Common in the east of Canterbury and Otago.

This is the common form of the steppe climate of the South Island. The leaves are concave on the upper surface, green, thicker and narrower (1·1 cm. at base) than those of the North Island and western Nelson plant (the type), which are flat, broad (3 cm. at base), and glaucous. The raceme is altogether less open than in the type, and the flowers are smaller. Seen side by side the two plants are most distinct, and can be separated at a glance. We are indebted to Mr. T. Keir, of Rangiora, for first pointing out the great difference between the two forms; in fact, he considered—and with much justice—that they were distinct species, but we hesitate so to treat them in the absence of a large series of specimens.

(3.) **Epilobium confertifolium** Hook. f.

The above name was restricted to the plant of the New Zealand subantarctic botanical province by Cockayne in 1904, and Cheeseman in 1909 has come to the same conclusion. This leaves the New Zealand forms hitherto referred to this species without a name. Of these forms there are probably more than one to which we are inclined to accord specific rank, but think it best to defer so doing until examining more abundant material, and, above all, testing their fixity by cultivation.

(4.) 1. **Anisotome Haastii** (F. Muell.) comb. nov. = *Ligusticum Haastii* F. Muell. ex Hook. f. in Handbk. of N.Z. Flora, p. 95, 1864.

2. **Anisotome filifolia** (Hook. f.) comb. nov. = *Ligusticum filifolium* Hook. f. in Handbk. of N.Z. Flora, p. 95, 1864.

3. **Anisotome carnosula** (Hook. f.) comb. nov. = *Ligusticum carnosulum* Hook. f. in Handbk. of N.Z. Flora p. 96, 1864.

4. **Anisotome pilifera** (Hook. f.) comb. nov. = *Ligusticum piliferum* Hook. f. in Handbk. of N.Z. Flora, p. 96, 1864.

Cockayne, following Bentham and Hooker, has in all his recent papers referred the New Zealand species of *Ligusticum* to *Aciphylla*. But, as Cheeseman points out (1909, p. 108), this latter genus is best limited to the *Aciphyllae* proper, a most distinct group, and if it be thought correct to limit *Ligusticum* to the northern species, then Hooker's genus *Anisotome* might well be revived for the reception of the southern species. This course we have taken, since we consider *Anisotome* a true antarctic genus, notwithstanding, as in the cases of *Nothofagus*, *Nothopanax*, and *Celmisia*, it has a strong northern affinity.

(5.) Nertera species.

The species of *Nertera* in the list, which occurs also on bogs in the Waimakariri Valley, differs from *N. depressa* in its orange-coloured pyriform drupe, that of the latter being globose and red; but we have no material, and are writing from memory, so are unable to give a name and description to the plant. Probably it has hitherto been mistaken for *N. depressa*, since the drupes on being dried would lose their distinctive shape.

(6.) Olearia arborescens (Forst. f.) comb. nov. = *Solidago arborescens* Forst. f. in Prodromus, p. 298, 1786.

This is the well-known *O. nitida* Hook. f. in Handbk. of N.Z. Flora, p. 125, and it is a great pity the name has to be changed in accordance with the rules of botanical nomenclature.

(7.) Celmisia spectabilis Hook. f.

A very distinct form was common on Prospect Hill. This is distinguished from the type by the leaves being not "entire or minutely serrulate" (Cheeseman, 1906, p. 308), but coarsely and distantly toothed almost to the base. Young leaves on a cultivated example exhibit the same toothing.

(B.) LIST OF SPECIES.

Species, Family, &c.	Plant-association.
PTERIDOPHYTA.	
FILICES.	
Hymenophyllum sanguinolentum (Forst. f.) Sw. ..	Totara forest.
—— *villosum* Col.	Rock, subalpine.
—— *tunbridgense* (L.) Sm.	Totara forest.
—— *multifidum* (Forst. f.) Sw.	Rock, subalpine.
Alsophila Colensoi Hook. f.	Subalpine scrub ?
Cystopteris fragilis (L.) Bernh.	Stony *débris* in montane belt of steppe climate.
Hypolepis millefolium Hook.	*Nothofagus* forest.
Histiopteris incisa (Thunb.) J. Sm.	Subalpine scrub, where it had been burned.
Pteridium esculentum (Forst. f.) Cockayne.	
Blechnum penna marina (Poir.) Kuhn	*Nothofagus* forest; steppe; fan.
—— *capense* (L.) Schlcht.	*Nothofagus* forest.
Asplenium flabellifolium Cav.	Totara forest.
—— *Richardi* Hook. f.	Rock (steppe climate); totara forest.
—— *flaccidum* Forst. f.	Totara forest.

List of Species—*continued.*

Species, Family, &c.	Plant-association.
Polystichum vestitum (Forst. f.) Presl.	*Débris* below rock (steppe climate); totara forest; *Nothofagus* forest.
——— *cystotegia* (Hook.) J. B. Armstg.	Stony *débris* (stable and large), alpine.
Polypodium Billardieri (Willd.) C. Chr.	Totara forest.
——— *pumilum* (J. B. Armstg.) Cockayne ..	Rock, subalpine.
Ophioglossum coriaceum A. Cunn.	Steppe.
LYCOPODIACEAE.	
Lycopodium Selago L.	Fell-field.
——— *varium* R. Br.	Totara forest.
——— *scariosum* Forst. f.	Steppe, but local.
SPERMOPHYTA.	
TAXACEAE.	
Podocarpus Hallii T. Kirk*	Totara forest.
——— *nivalis* Hook.	Subalpine scrub (Cameron Glacier); *Nothofagus* forest, on outskirts.
Dacrydium Bidwillii Hook. f.	*Sphagnum* bog; lake, margin of, on bank.
Phyllocladus alpinus Hook. f.	Totara forest; subalpine scrub.
PINACEAE.	
Libocedrus Bidwillii Hook. f.	Totara forest.
TYPHACEAE.	
Typha angustifolia L. var. *Muelleri ?* (Rohrb.) Graebn.	Lake.
GRAMINEAE.	
Microlaena Colensoi (Hook. f.) Petrie	Rock, alpine.
Hierochloe redolens (Forst. f.) R. Br.	Fell-field.
——— *Fraseri* Hook. f.	Steppe; river-bed, subalpine.
Agrostis subulata Hook. f.	Rock, alpine.
——— *Dyeri* Petrie	Steppe; fell-field.
Deyeuxia setifolia Hook. f.	Fell-field.
——— *avenoides* (Hook. f.) Buch.	Steppe.
Dichelachne crinita (Forst. f.) Hook. f.	Steppe.
Trisetum antarcticum (Forst. f.) Trin.	Steppe; fell-field.
——— *Youngii* Hook. f.	Steppe of subalpine river-bed.
——— *subspicatum* Beauv.	Rock, alpine.
Danthonia Raoulii Steud.	Steppe.
——— *flavescens* Hook. f.	Steppe; fell-field.
——— *semiannularis* R. Br.	Steppe; rock, montane and subalpine.
——— ——— var. *setifolia* Hook. f.	Steppe; fell-field.
——— *Buchanani* Hook. f.	Steppe.
Arundo conspicua Forst. f.	River-bed, montane.
Triodia exigua T. Kirk	Steppe.
Poa novae-zealandiae Hack.	Rock, subalpine.
——— *anceps* Forst. f. (?) var.†	Fell-field; coarse and fairly stable shingle-slip; steppe of river-bed.

* Our notes regarding the species of totara are quite insufficient, nor have we any specimens beyond one piece of bark which is evidently that of *P. Hallii*. On the other hand, *P. totara* may also be present, especially at the lowest altitude of the forest.

† This grass is possibly an undescribed species. It is probably common on the wet mountains of the central Southern Alps.

LIST OF SPECIES—*continued.*

Species, Family, &c.	Plant-association.
Poa caespitosa Forst. f.	Steppe; rock; fell-field.
Colensoi Hook. f.	Steppe; rock; fell-field.
var. *intermedia* (Buch.) Cheesem.	Steppe.
— *Kirkii* Buch.	Steppe.
Lindsayi Hook. f.	Steppe.
maniototo Petrie	Steppe.
Festuca ovina L. var. *novae-zealandiae* Hack.	Steppe; river-bed, subalpine.
— *rubra* L. var.	Steppe.
Agropyron scabrum (R. Br.) Beauv.	Steppe; rock.
CYPERACEAE.	
Eleocharis Gunninghamii Boeck.	Swamp; lake; *Sphagnum* bog.
Schoenus pauciflorus Hook. f.	*Sphagnum* bog; swamp.
Oreobolus pectinatus Hook. f.	*Sphagnum* bog.
Uncinia compacta R. Br.	Steppe; river-bed, subalpine.
— — *uncinata* (L. f.) Kükenth.	Totara forest.
— — *fusco-vaginata* Kükenth.	Fell-field.
— — *rubra* Boott	Steppe.
filiformis Boott	Totara forest.
Carex kaloides Petrie	Wet ground.
diandra Schrank	Swamp.
Colensoi Boott	Steppe.
— *stellulata* Good	Swamp.
— *subdola* Boott	Swamp.
— *Gaudichaudiana* Kunth.	Swamp; *Sphagnum* bog.
— — *ternaria* Forst. f.	Swamp.
— — *wakatipu* Petrie	River-bed.
— — *Buchanani* Berggr.	Stream, margin of.
— — *Petriei* Cheesem.	River-bed, in damp ground.
— — *breviculmis* R. Br.	Steppe.
— — *Oederi* Retz var. *cataractae* (R. Br.) Kükenth.	Swamp.
JUNCACEAE.	
Juncus effusus L.	Lake; swamp.
— — *bufonius* L.	River-bed, montane.
Luzula pumila Hook. f.	Fell-field, alpine.
— *campestris* D. C. var.	Steppe; river-bed, subalpine.
racemosa Desv.	Steppe.
— *ulophylla* (Buchen.) Cockayne and Laing	Steppe; river-bed.
LILIACEAE.	
Astelia montana (T. Kirk) Cockayne	Fell-field.
Petriei Cockayne	Fell-field.
Phormium Cookianum Le Jolis	Subalpine scrub; fell-field.
Bulbinella Hookeri (Col.) Benth. & Hook. var. *angustifolia* Cockayne and Laing	Steppe; bog.
ORCHIDACEAE.	
Microtis unifolia (Forst. f.) Reichenb.	Steppe.
Prasophyllum Colensoi Hook. f.	Steppe.
Pterostylis mutica R. Br.	Steppe.
Corysanthes (*macrantha* Hook. f.) ?	Totara forest.
FAGACEAE.	
Nothofagus cliffortioides (Hook. f.) Oerst.	*Nothofagus* forest; bank of streams as occasional scattered clumps.
URTICACEAE.	
Urtica incisa Poir.	Totara forest; *Nothofagus* forest.

LIST OF SPECIES—*continued.*

Species, Family, &c.	Plant-association.
LORANTHACEAE.	
Elytranthe flavida (Hook. f.) Engler	*Nothofagus* forest.
Tupeia antarctica (Forst. f.) Cham. & Schlecht.	Totara forest; subalpine scrub.
POLYGONACEAE.	
Rumex flexuosus Sol.	Steppe.
Muehlenbeckia australis (Forst. f.) Meissn.	Totara forest.
——— *complexa* (A. Cunn.) Meissn.	Totara forest; scrub of river-bed.
——— *axillaris* Walp.	River-bed; steppe.
——— *ephedroides* Hook. f.	Steppe.
PORTULACACEAE.	
Claytonia australasica Hook. f.	Shingle-slip; stream.
Montia fontana L.	Stream.
CARYOPHYLLACEAE.	
Stellaria Roughii Hook. f.	Shingle-slip.
Colobanthus quitensis Bartl.	Steppe.
——— *Billardieri* Fenzl.	Steppe.
——— *brevisepalus* T. Kirk	Steppe.
——— *acicularis* Hook. f.	Rock.
Scleranthus biflorus (Forst.) Hook. f.	Steppe; river-bed.
Hectorella caespitosa Hook. f.	Rock, alpine.
RANUNCULACEAE.	
Clematis australis T. Kirk	Subalpine scrub.
——— *marata* J. B. Armstg.	
Ranunculus Lyallii Hook. f.	Fell-field.
——— *Godleyanus* Hook. f.	Fell-field; bank of stream on river-bed.
——— *Monroi* Hook. f. var. *dentatus* T. Kirk	Rock, subalpine; fell-field.
——— *Haastii* Hook. f.	Shingle-slip.
——— *crithmifolius* Hook. f.	Shingle-slip.
——— *hirtus* Banks & Sol.	Steppe.
——— *lappaceus* Sm. var. *multiscapus* Hook. f.	Steppe.
——— *foliosus* T. Kirk	Steppe of subalpine river-bed.
——— *Cheesemanii* T. Kirk	River-bed, in wet ground.
——— *macropus* Hook. f.	Swamp; stream.
——— *rivularis* Banks & Sol.	Swamp.
Caltha novae-zelandiae Hook. f.	Fell-field.
CRUCIFERAE.	
Nasturtium palustre D. C.	River-bed, moist.
Cardamine heterophylla (Forst. f.) O. E. Schultz.	
——— *depressa* Hook. f.	Rock, subalpine.
Notothlaspi rosulatum Hook. f.	Shingle-slip.
DROSERACEAE.	
Drosera arcturi Hook.	*Sphagnum* bog.
CRASSULACEAE.	
Crassula Sieberiana Schultz	Rock.
SAXIFRAGACEAE.	
Carpodetus serratus Forst.	Totara forest.
PITTOSPORACEAE.	
Pittosporum tenuifolium Banks & Sol.	Totara forest.

LIST OF SPECIES—*continued.*

Species, Family, &c.	Plant-association.
ROSACEAE.	
Rubus schmidelioides A. Cunn. var. *coloratus* T. Kirk	Totara forest.
— *subpauperatus* Cockayne	Totara forest; scrub of river-bed.
— *australis* Forst. f.	Totara forest.
— *cissoides* A. Cunn.	
Geum parviflorum Sm.	Fell-field.
— *urbanum* L. var. *strictum*	River-bed.
Potentilla anserina L. var. *anserinoides* (Raoul) T. Kirk	Swamp.
Acaena Sanguisorbae Vahl. var. *pilosa* T. Kirk*	Steppe; fell-field.
— *inermis* Hook. f.	Steppe.
— *microphylla* Hook. f.	Steppe.
LEGUMINOSAE.	
Carmichaelia Enysii T. Kirk	Steppe.
— *uniflora* T. Kirk	Steppe.
— *nana* Col.	Steppe.
— *Monroi* Hook. f.	Steppe.
— *grandiflora* Hook. f.	Subalpine scrub; river-bed, subalpine.
Swainsona novae-zealandiae Hook. f.	Shingle-slip.
Sophora microphylla Ait.	Totara forest.
GERANIACEAE.	
Geranium microphyllum Hook. f.	Steppe; *Sphagnum* bog.
— *sessiliflorum* Cav.	Steppe.
OXALIDACEAE.	
Oxalis corniculata L.	Steppe.
— *magellanica* Forst.	Fell-field.
CORIARIACEAE.	
Coriaria ruscifolia L.	Steppe.
— *thymifolia* Humb. & Bonpl.	River-bed, steppe; fell-field.
— *angustissima* Hook. f.	River-bed, steppe; fell-field.
STACKHOUSIACEAE.	
Stackhousia minima Hook. f.	Steppe.
RHAMNACEAE.	
Discaria toumatou Raoul	Steppe; river-bed; rock.
ELAEOCARPACEAE.	
Aristotelia fruticosa Hook. f.	Subalpine scrub.
MALVACEAE.	
Gaya Lyallii (Hook. f.) J. E. Baker	Totara forest; subalpine scrub.
— *ribifolia* (F. Muell.) Cockayne	*G. ribifolia* association.
GUTTIFERAE.	
Hypericum gramineum Forst. f.	Steppe.
VIOLACEAE.	
Viola Cunninghamii Hook. f.	*Sphagnum* bog; fell-field.
Hymenanthera dentata R. Br. var. *alpina* T. Kirk	Fell-field; *débris* below cliff.

* This is probably *Acaena Sanguisorbae* subspecies *caesiiglauca* Bitter.

LIST OF SPECIES—*continued.*

Species, Family, &c.	Plant-association.
THYMELIACEAE.	
Pimelea Traversii Hook. f.	Rock, subalpine.
——— *laevigata* Gaertn. var. *repens* Cheesem. ..	Steppe.
——— *Lyalli* Hook. f.	Steppe; fell-field.
Drapetes Dieffenbachii Hook.	Steppe; fell-field.
MYRTACEAE.	
Leptospermum scoparium Forst.	Steppe.
ONAGRACEAE.	
Epilobium chionanthum Haussk.	Swamp.
——— *pubens* A. Rich.	Totara forest; rock.
——— species*	Fell-field.
——— *Hectori* Haussk.	Steppe.
——— *chloraefolium* Haussk.	*Sphagnum* bog; fell-field.
——— *nummularifolium* R. Cunn.	Rock, in shade.
——— *pedunculare* A. Cunn.	River-bed; steppe.
——— *macropus* Hook.	Stream.
——— (*crassum* Hook. f.) ?†	Rock.
——— *pycnostachyum* Haussk...	Shingle-slip.
——— *melanocaulon* Hook.	River-bed.
——— *rostratum* Cheesem.	River-bed.
——— *microphyllum* A. Rich.	River-bed.
——— *glabellum* Forst. f.	River-bed.
——— *elegans* Petrie	Steppe.
Fuchsia excorticata L. f.	Totara forest; *Nothofagus* forest.
HALORRHAGACEAE.	
Halorrhagis unifolia T. Kirk (= *H. depressa* Walp. var. *unifolia* (T. Kirk) Cheesem. in Trans. N.Z. Inst., vol. 42, p. 203, 1910)	Steppe.
——— *micrantha* R. Br.	Bog.
Myriophyllum elatinoides Gaud.	Stream; lake.
Gunnera (*monoica* Raoul) ? var.	Bog.
——— *dentata* T. Kirk..	Stream.
ARALIACEAE.	
Nothopanax simplex (Forst. f.) Seem.	Totara forest; subalpine scrub.
——— *parvum* (T. Kirk) Cockayne	Subalpine scrub of river-bed.
——— *Colensoi* (Hook. f.) Seem.	Subalpine scrub; totara forest.
Pseudopanax crassifolium (Sol.) C. Koch var. *unifoliatum* T. Kirk	Totara forest.
UMBELLIFERAE.	
Hydrocotyle novae-zelandiae D. C.	Steppe.
——— *americana* L.	Steppe.
Schizeilema nitens (Petrie) Domin.	Stream.
Oreomyrrhis andicola Endl. var. *Colensoi* (Hook. f.) T. Kirk	Steppe.
——— ——— var. *ramosa* (Hook. f.) T. Kirk ..	Steppe.
Crantzia lineata Nutt.	Bog.

* = one or more of the series of forms hitherto included by J. D. Hooker, T. Kirk, Cheeseman, and others with *E. confertifolium* Hook. f. of the New Zealand subantarctic islands.

† Specimens poor; it may be *E. brevipes*.

List of Species—*continued.*

Species, Family, &c.	Plant-association.
Aciphylla Colensoi Hook. f.	Steppe.
var. *maxima* T. Kirk	Subalpine scrub.
squarrosa Forst.	Steppe.
—— *Monroi* Hook. f.	Rock, subalpine; fell-field.
Anisotome Haastii (F. Muell.) Cockayne and Laing..	Fell-field.
—— *filifolia* (Hook. f.) Cockayne and Laing	Shingle-slip; steppe.
—— *carnosula* (Hook. f.) Cockayne and Laing ..	Shingle-slip.
—— *pilifera* (Hook. f.) Cockayne and Laing ..	Rock; fell-field.
—— var. *pinnatifida* T. Kirk	Fell-field.
—— *aromatica* Hook. f.	Steppe; fell-filled: *Sphagnum* bog.
Angelica Gingidium (Forst. f.) Hook. f.	Fell-field; steppe; river-bed.
—— *decipiens* Hook. f.	Steppe.
Cornaceae.	
Griselinia littoralis Raoul	Totara forest; subalpine scrub.
Ericaceae.	
Gaultheria depressa Hook. f.	Steppe; *Sphagnum* bog.
—— *perplexa* T. Kirk	Subalpine scrub of river-bed.
—— *rupestris* (Forst. f.) R. Br.	Rock; fell-field.
Pernettya nana Col.	Steppe.
Epacridaceae.	
Pentachondra pumila (Forst. f.) R. Br.	Fell-field.
Styphelia acerosa Sol.	Fell-field.
—— *Colensoi* (Hook. f.) Diels..	Fell-field; steppe.
—— *Fraseri* (A. Cunn.) F. Muell.	Steppe; river-bed; fell-field.
Archeria Traversii Hook. f.	Subalpine scrub.
Dracophyllum longifolium (Forst. f.) R. Br. ..	Totara forest; subalpine scrub.
—— *Urvilleanum* A. Rich. var. *montanum* Cheesem.	Subalpine scrub.
—— *Kirkii* Berggr.	Rock, subalpine.
—— *uniflorum* Hook. f.	Fell-field.
—— *rosmarinifolium* (Forst. f.) R. Br.	Rock; fell-field.
Myrsinaceae.	
Suttonia divaricata Hook. f.	Totara forest; subalpine scrub.
—— *nummularia* Hook. f.	Rock, subalpine.
Gentianaceae.	
Gentiana Grisebachii Hook. f.	Steppe.
—— *bellidifolia* Hook. f.	Fell-field.
Apocynaceae.	
Parsonsia capsularis var.	Subalpine scrub of river-bed.
Borraginaceae.	
Myosotis Traversii Hook. f.	Shingle-slip.
—— species (perhaps a form of *M. antarctica* Hook. f.)	Fell-field.
—— *australis* R. Br.	Steppe.
—— *Forsteri* Lehm. ..	Shady bank, subalpine.
Labiatae.	
Mentha Cunninghamii (A. Cunn.) Benth. ..	Steppe; bog.
Scrophularinaceae.	
Mazus radicans (Hook. f.) Cheesem. ..	Bog.
(*Glossostigma elatinoides* Benth.)? ..	Swamp.

LIST OF SPECIES—*continued.*

Species, Family, &c.	Plant-association.
Veronica salicifolia Forst. f.	Subalpine scrub; totara forest.
——— ——— var. *Kirkii* (J. B. Armstg.) Cheesem.	Subalpine scrub ?
——— *leiophylla* Cheesem.	Scrub on limestone, montane.
——— *subalpina* Cockayne	Subalpine scrub.
——— *buxifolia* Benth. var. *odora* T. Kirk ..	Steppe, near stream.
——— *anomala* J. B. Armstg.	Habitat ? (Rakaia Gorge, E. Stead !).
——— *amplexicaulis* J. B. Armstg.	Fell-field.
——— *pinguifolia* Hook. f.	Fell-field.
——— *pimelioides* Hook. f. var. *minor* Hook. f. ..	Steppe.
——— *tetrasticha* Hook. f.	Rock, subalpine.
——— *lycopodioides* Hook. f.	Fell-field.
——— *Armstrongii* T. Kirk	Habitat ?*
——— *cupressoides* Hook. f.	Habitat ?†
——— *Haastii* Hook. f.	Shingle-slip.
——— *epacridea* Hook. f.	Shingle-slip; rock.
——— *macrantha* Hook. f.	Fell-field.
——— *pulvinaris* (Hook. f.) Benth. & Hook. f. ..	Fell-field.
——— *loganioides* J. B. Armstg.	Fell-field.
——— *Lyallii* Hook. f.	River-bed, subalpine.
——— ——— var. *suberecta* Cheesem.	Rock, shaded, subalpine.
——— *Bidwillii* Hook. f.	River-bed.
Ourisia macrocarpa Hook. f.	Fell-field.
——— (*Colensoi* Hook. f.) ?	Fell-field.
——— *sessiliflora* Hook. f.	Fell-field.
——— *caespitosa* Hook. f.	Fell-field.
Euphrasia Monroi Hook. f.	Fell-field.
LENTIBULARIACEAE.	
Utricularia monanthos Hook. f.	*Sphagnum* bog.
PLANTAGINACEAE.	
Plantago Brownii Rapin	Bog, subalpine.
——— *spathulata* Hook. f.	Steppe.
——— *triandra* Bergg.	Bog.
RUBIACEAE.	
Coprosma serrulata Hook. f.	Fell-field.
——— *rhamnoides* A. Cunn.	Subalpine scrub.
——— *ciliata* Hook. f.	Subalpine scrub; totara forest.
——— *parviflora* Hook. f.	Subalpine scrub; totara forest.
——— *ramulosa* Petrie	Fell-field.
——— *brunnea* (T. Kirk) Cockayne	River-bed.
——— *rugosa* Cheesem.	River-bed, subalpine; subalpine scrub.
——— (*propinqua* A. Cunn.) ?	*Nothofagus* forest.
——— *linariifolia* Hook. f.	Totara forest.
——— *cuneata* Hook. f.	Rock, alpine; fell-field.
——— *Petriei* Cheesem.	Steppe.
Nertera species (probably distinct from *N. depressa* Banks & Sol.)	Bog.
Galium umbrosum Sol.	Habitat ?
Asperula perpusilla Hook. f.	River-bed; bog.
CAMPANULACEAE.	
Pratia angulata (Forst. f.) Hook. f.	Steppe; bog.
——— *macrodon* Hook. f.	Fell-field.

* Not seen by us, but the original description gives the Upper Rangitata.

† Probably fairly common originally, but now destroyed for the most part by fire.

LIST OF SPECIES—*continued.*

Species, Family, &c.	Plant-association.
Lobelia linnaeoides (Hook. f.) Petrie	Fell-field.
——— *Roughii* Hook. f.	Shingle-slip.
Wahlenbergia gracilis (Forst. f.) A. D. C.	Steppe.
——— *saxicola* (R. Br.) A. D. C.	Steppe; fell-field.
STYLIDIACEAE.	
Phyllachne Colensoi (Hook. f.) Bergg.	Fell-field.
Donatia novae-zelandiae Hook. f.	Bog, subalpine.
Forstera Bidwillii Hook. f.	Fell-field.
——— *tenella* Hook. f.	Steppe.
COMPOSITAE.	
Lagenophora petiolata Hook. f.	Steppe.
——— *Barkeri* T. Kirk	Habitat ?
Brachycome pinnata Hook. f.	Steppe.
——— *Sinclairii* Hook. f.	Steppe.
Olearia arborescens (Forst. f.) Cockayne and Laing	Subalpine scrub.
——— *macrodonta* Baker	Subalpine scrub.
——— *ilicifolia* Hook. f.	Totara forest; subalpine scrub.
——— *moschata* Hook. f.	Subalpine scrub.
——— *Haastii* Hook. f.	Subalpine scrub.
——— *oleifolia* T. Kirk	Subalpine scrub.
——— *nummularifolia* Hook. f.	Subalpine scrub.
——— *cymbifolia* (Hook. f.) Cheesem.	Subalpine scrub.
——— *avicenniaefolia* Hook. f.	Subalpine scrub.
——— *virgata* Hook. f.	Steppe.
Celmisia Walkeri T. Kirk (not typical, but nearer this than to *C. discolor*)	Rock, subalpine.
——— *discolor* Hook. f.	Fell-field.
——— *Sinclairii* Hook. f.	Fell-field; rock.
——— *Haastii* Hook. f.	Fell-field, alpine.
——— *petiolata* Hook. f.	Rock, subalpine, on raw humus; fell-field.
——— *spectabilis* Hook. f.	Steppe; fell-field.
——— *pseudo-Lyallii* (Cheesem.) Cockayne	Fell-field.
——— *coriacea* (Forst. f.) Hook. f.	Fell-field.
——— *Lyallii* Hook. f.	Fell-field.
——— *viscosa* Hook. f.	Fell-field.
——— *longifolia* Cass.	Steppe; bog.
——— *laricifolia* Hook. f.	Fell-field.
——— *sessiliflora* Hook. f.	Fell-field.
——— *bellidioides* Hook. f.	Rock, subalpine
Vittadinia australis A. Rich.	Steppe.
Haastia Sinclairii Hook. f.	Shingle-slip, alpine.
Gnaphalium Traversii Hook. f.	Steppe.
——— *paludosum* Petrie	Bog.
——— *luteo-album* L.	Steppe; river-bed.
——— *japonicum* Thunb.	Steppe.
——— *collinum* Lab.	Steppe.
Raoulia australis Hook. f.	River-bed.
——— *lutescens* (T. Kirk) Cockayne	River-bed; steppe.
——— *tenuicaulis* Hook. f.	River-bed.
——— *Haastii* Hook. f.	River-bed.
——— *Monroi* Hook. f.	Steppe.
——— (*apice-nigra* T. Kirk) ?	Steppe.
——— *subsericea* Hook. f.	Steppe.
——— *eximia* Hook. f.	Rock, alpine.
——— *grandiflora* Hook. f.	Fell-field.

LIST OF SPECIES—*continued.*

Species, Family, &c.	Plant-association.
Helichrysum bellidioides (Forst. f.) Willd.	Steppe;
——— *filicaule* Hook. f. . . .	Steppe.
——— *grandiceps* Hook. f.	Rock.
——— *depressum* (Hook. f.) Benth. & Hook. f. .	River-bed.
——— *microphyllum* (Hook. f.) Benth. & Hook. f..	Rock.
——— *Selago* (Hook. f.) Benth. & Hook. .	Rock.
Cassinia Vauvilliersii (Homb. & Jacq.) Hook. f. .	Steppe.
——— *fulvida* Hook. f.	Steppe.
Craspedia uniflora Forst. f. var. .. .	Steppe; river-bed.
——— *alpina* Backhouse	Shingle-slip.
Cotula atrata Hook. f.	Shingle-slip.
——— *pyrethrifolia* Hook. f.	Fell-field.
——— *perpusilla* Hook. f.	Steppe.
——— *squalida* Hook. f.	Steppe.
Erechtites glabrescens T. Kirk	Totara forest.
Senecio bellidioides Hook. f.	Steppe.
——— *scorzoneroides* Hook. f.	Fell-field.
——— *lautus* Forst. f. var. *montanus* Cheesem. ..	Shingle-slip.
——— *cassinioides* Hook. f.	Subalpine scrub.
——— *elaeagnifolius* Hook. f.	Subalpine scrub.
——— *Bidwillii* Hook. f. var. *viridis* (T. Kirk) Cheesem.	Subalpine scrub.
Microseris Forsteri Hook. f.	Steppe.
Crepis novae-zelandiae Hook. f.	Rock.
Taraxacum glabratum (Forst. f.) Cockayne .	Fell-field.

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Art. XXXVIII.—*The Younger Rock-series of New Zealand.*

By P. Marshall, D.Sc., F.G.S., Professor of Geology, Otago University; R. Speight, M.Sc., F.G.S., Lecturer on Geology, Canterbury College; and C. A. Cotton, M.Sc., Lecturer on Geology, Victoria College.

[*Read before the Otago Institute, 1st November, 1910.*]

Plate VIII.

[Note.—This paper has been mainly written by the first author. The observations upon which it is based were made conjointly by the three authors in the typical districts of North Canterbury. Other districts referred to have been examined by only two or by one of the authors, but in each case the observations made have been referred in detail to the others, and the authors are in complete agreement in regard to all the critical points set forth in the paper. The critical account of the stratigraphical relations of the Waitemata series has been kindly furnished by Mr. E. de C. Clarke, of the University College, Auckland, and the authors are specially indebted to him for the description of this important locality.]

Table of Contents.

I. INTRODUCTION.

THE stratigraphical relations of the series of younger rocks of New Zealand has presented a problem which each geological observer who has worked

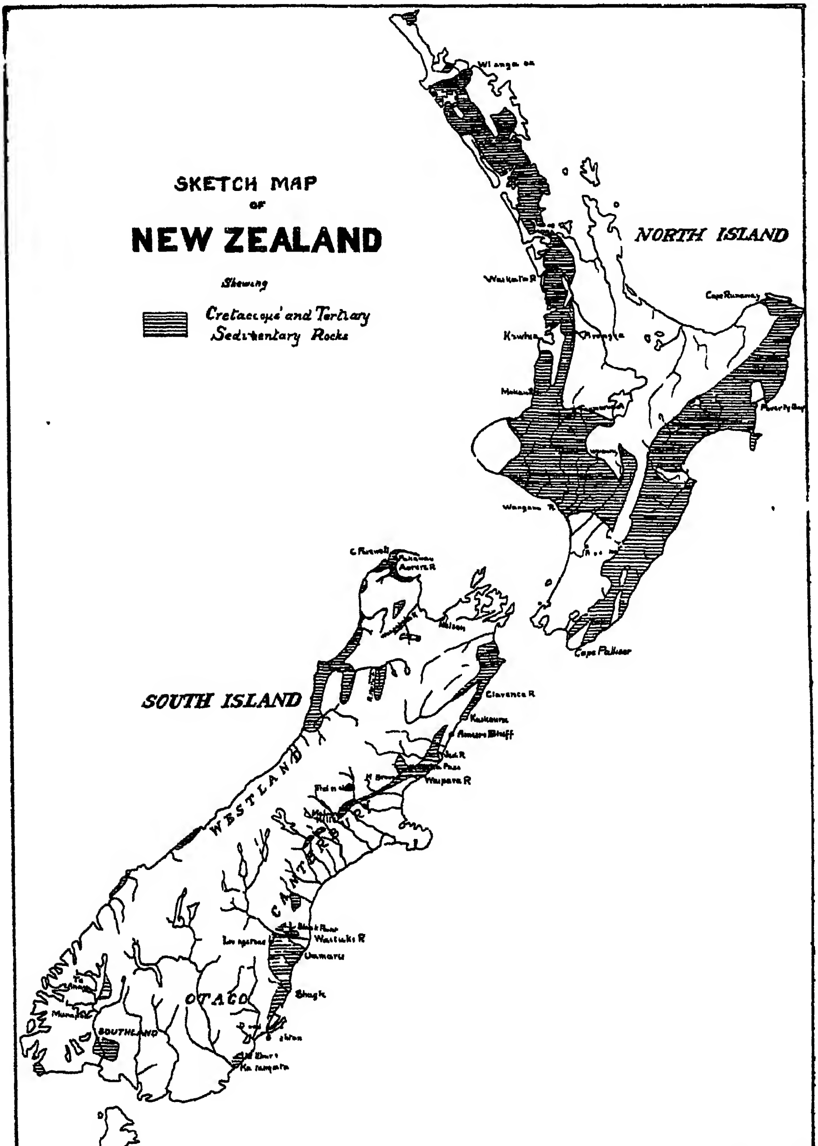


FIG 1.

at them has solved in a different way from all of the others. This obviously implies that elements of difficulty and confusion are involved in a treatment of the question.

The distribution of the series is fairly general in the coastal districts of both Islands and in some portions of the interior parts, but in most instances the outcrops are separated from one another (see fig. 1). In all but a very few of the areas where the series is exposed the stratification is simple. In many cases the strata lie flat; but where they border on an older series of rocks they are generally inclined and folded in some simple manner, though in some places it causes them to lie vertically. It is the belief of the authors that the mere stratigraphy would have offered no difficulties and have caused no confusion if there had not been other matters requiring consideration in connection with the whole question. One of these other matters is the correlation of the strata in the different and sometimes distant areas where they outcrop, but the most important is to be found in the palaeontological succession. The lowest strata of this younger series contain fossils that are generally allowed to be of Cretaceous age, the upper of Miocene or Pliocene age.

In general the rocks are marginal. In the North Island they unite in the extreme north portions of the older rocks that crop out here and there, and apparently constitute the greater part of the country as far south as the Upper Waikato. They are extensively developed on the eastern side of the great range from Cape Runaway to Cape Turakirae, and in places near the East Cape form the highest part of the country.

In the south part of this coast they are replaced by older series, but in the central part they extend almost from side to side of the Island except for a narrow ridge of old rocks. On the western side they form the whole country between a line through Pirongia, Taumarunui, Waiouru, Waikanae and the coast.

In the South Island the formation is more restricted and local, and is nearly always marginal. It extends up many river-valleys—Aorere, Clarence, Waitaki, for example. It is widely extended in North Canterbury, in North Otago, and again in Southland; while it occupies interior basins in the Te Anau and Manapouri districts, as well as at Trelissick. In Westland the development is again larger in the northern part, and especially large areas are found in the Wangapeka, Maruia, and other valleys. Occasionally the rocks are well folded into much older series, as at Nelson, where they occur structurally involved in strata of Trias-jura age.

Recognition of this has caused various observers to seek for unconformities in the strata, for different members of the series contain extremely different faunas. Unconformities have been described by every observer and they have been placed in different positions in the series by every observer, and in almost every case the breaks recognized by one have not been admitted by others.

In all exposures there is, however, a well-marked lithological series, so far as the observations of the present authors have gone, and this series will be stated in some detail when treating of the different areas. So similar is the succession in the various localities that it is possible without any great error to state a generalized rock-succession that will apply with considerable exactness to the many occurrences. This is as follows:—

7. Loose sands with shells.
6. Mount Brown beds; sands often calcareous.
5. Grey marls.
4. Greensands.
3. Limestone.
2. Greensand.
1. Sands, conglomerates with coal.

This series, of course, varies considerably in different localities. Some members may be quite omitted, while others are relatively thick. In general, it is thought that the following statement represents, without attention to purely local features, the variations that are found in different localities.

In North Canterbury practically the whole series is present. In Otago it is unusual to find any beds higher in the series than the limestone. In Westland and at Cape Farewell and Shag Point the basal conglomerate is of great thickness - 7,000 ft. in the first case - and it contains important seams of coal.

In the North Island, but more particularly in its southern portions, there is an immense development of the grey marls, which in the Wanganui country are perhaps 2,000 ft. thick. The greensands are highly variable in thickness, and are often absent; they have a particularly large development in North Canterbury. The limestone is fairly general, and the most constant member of the series, but landwards always becomes somewhat sandy, and even passes into pure quartz sand where it is marginal to the old land.

As will be more fully mentioned later, the fossils contained in the rocks at the base of the series are wholly different from those at the top; in fact, the lowest rocks, in some localities at least, contain Mesozoic forms, and have been referred by all observers to the Cretaceous period. On the other hand, there is a high percentage of Recent species in the highest rocks, and they are classed as Upper Miocene or Pliocene on all hands.

It appears to have been the general belief of those geologists who have examined these rocks that a rock-series showing evidence of such great difference in age in its lowest and highest members could not have been deposited in a uniform stratigraphical sequence as a single formation. It has therefore been thought necessary by all authorities to refer different portions of the rock-sequence to different geological systems the members of which are supposed to be separated by unconformities. Unfortunately, while there has been an agreement in principle, there has been a marked divergence in practice, and no two authorities have placed the unconformities in the same places. This is the more remarkable as in nearly all localities where the rocks occur there is a fine exposure of natural sections in which the rock-series are displayed free from all obscurity, and in most cases with nothing but folding of a most simple description.

The great variety of opinion in regard to this matter is shown in the following summary of the classifications adopted by those geologists who have published comprehensive works dealing with the geology of the whole or of large portions of the Dominion.

II. Classifications employed.

(*a*.) *Hochstetter* ("Reise der 'Novara': Geologie," vol. 1, p. 39. Wien, 1864).

Kainozoic Series.—(1.) Older Tertiary System: (*a*) Brown coals, Lower—Coalfields of Drury, Waikato, North Auckland, Nelson, Otago; (*b*) Marine series, Upper — Waitemata, Kawhia, and Aotea, Motupipi (Nelson), Aorere (Nelson), gold-bearing conglomerate (Aorere), white and yellow calcareous sands and greensands with limestone, Oamaru, Green Island, Shag Valley. (2.) Younger Tertiary: Cape Rodney, Hawke's Bay, Wanganui River, Nelson cliffs, blue clay of Awatere, Waitaki, Moeraki.

(*b.*) *Hutton* (Q.J.G.S., 1885).

Wanganui System (Pliocene). — Newer Pliocene: Locality names — Kereru, Ormond, Petane, and Putiki series. Older Pliocene: Older glacial deposits—Lignites of Otago, Manukau, &c.

Pareora System (Miocene).—Localities: Awatere (Marlborough), Kanieri (Westland), Tawhiti (Poverty Bay), Ahuiri (Hawke's Bay), Waitemata (Auckland), brown coal of Pomahaka (Southland).

Oamaru System (Oligocene).—Localities: Mount Brown (North Canterbury), Aotea (south-west Auckland), Ototara (Oamaru), Turanganui (Poverty Bay), coals of Waikato, Kaitangata.

Waipara System (Upper Cretaceous).—Localities: Amuri (Marlborough), Awanui (Poverty Bay), Matakea (North Otago), coals of Greymouth, Pakawau (North Nelson).

(*c.*) *Haast* ("Geology of Canterbury and Westland," p. 251. Christchurch, 1879).

Waipara.—Cretaceo-tertiary.
Oamaru.—Upper Eocene or Lower Miocene.
Pareora.—Upper Miocene or Lower Pliocene.

(*d.*) *Hector* (Handbook of N.Z.: Geology. Wellington, 1886: Government Printer).

Lower Greensand. — (*a*) Buller series; (*b*) Porphyry breccia series; (*c*) Amuri series.

Cretaceo-tertiary.—(*a*) Grey Marls; (*b*) Ototara series; (*c*) Mawhera series; (*d*) Chalk series; (*e*) Waireka series; (*f*) Coal series; (*g*) Black Grit series; (*h*) Propylite breccia series; (*i*) Great Conglomerate series.

Upper Eocene.—(*a*) Mount Brown series; (*b*) Oamaru series; (*c*) Waitaki series.

Lower Miocene.—(*a*) Awatere series; (*b*) Pareora series; (*c*) Awamoa series; (*d*) Lignite.

Upper Miocene.—(*a*) Te Aute series; (*b*) Taueru series.

Pliocene.—(*a*) Dispersed gravels; (*b*) Napier series; (*c*) Lignite series; (*d*) Kereru series.

(*e.*) *Park* (Geology of N.Z., 1910, p. 25).

Amuri System.—Waipara series (Cretaceous): (*a*) Weka Pass stone and Grey Marls; (*b*) Amuri limestone; (*c*) Waipara greensands; (*d*) Saurian beds; (*e*) Puke-iwi-tahi conglomerates and sandstone with coal.

Karamea System.—Waimangaroa series (Eocene): (*a*) Brunner coal; (*b*) Paparoa coal.

Oamaru Series (Miocene).—(*a*) Ototara stone; (*b*) Pareora beds; (*c*) Marawhenua beds; (*d*) Waihao beds; (*e*) Kaikorai coal-measures.

Wanganui System.—(*a*) Petane series (newer Pliocene); (*b*) Waitotara series, (*c*) Awatere series (older Pliocene).

(*f.*) *Comparisons of these Opinions.*

The nature of this divergence of opinion appears more striking when shown diagrammatically (fig. 2), for then it is seen that a total of five unconformities have been described by different observers, and as many as three in the North Canterbury series by a single authority; while if the series is extended to the highest member in the North Island the number of

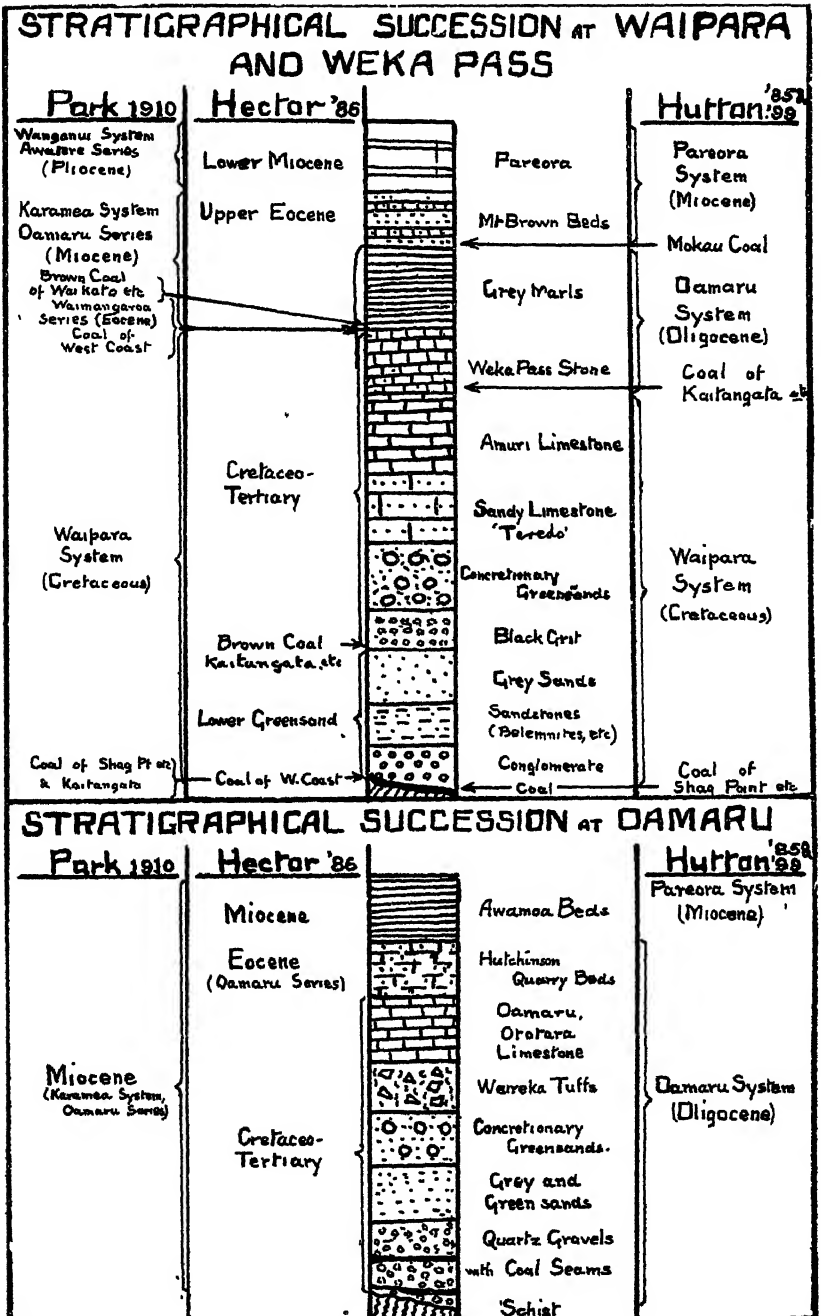

STRATIGRAPHICAL SUCCESSION AT WAIPARA AND WEKA PASS
Park 1910
Hector '86
Hutton '85 '99
Wanganui System Awatere Series (Pliocene)
Karamea System Oamaru Series (Miocene)
Brown Coal of Waikato etc.
Waimangaroa Series (Eocene)
Coal of West Coast
Waipara System (Cretaceous)
Coal of Shag Pt etc & Kaitangata
Lower Miocene
Upper Eocene
Cretaceo-Tertiary
Brown Coal Kaitangata etc
Lower Greensand
Coal of W. Coast
Pareora
Mt Brown Beds
Grey Marls
Weka Pass Stone
Amuri Limestone
Sandy Limestone 'Teredo'
Concretionary Greensands
Black Grit
Grey Sands
Sandstones (Belemnites, etc)
Conglomerate
Coal
Pareora System (Miocene)
Mokau Coal
Oamaru System (Oligocene)
Coal of Kaitangata etc
Waipara System (Cretaceous)
Coal of Shag Point etc
STRATIGRAPHICAL SUCCESSION AT OAMARU
Park 1910
Hector '86
Hutton '85 '99
Miocene (Karamea System, Oamaru Series)
Miocene
Eocene (Oamaru Series)
Cretaceo-Tertiary
Awamoa Beds
Hutchinson Quarry Beds
Oamaru, Ototara Limestone
Waireka Tuffs
Concretionary Greensands.
Grey and Green sands
Quartz Gravels with Coal Seams
Schist
Pareora System (Miocene)
Oamaru System (Oligocene)

FIG. 2.

unconformities inserted by Hector is five. Some of these unconformities that are inserted represent great lapses of time. Thus the plane between the Waipara and Karamea systems of Park represents a period of erosion extending throughout the Eocene and Oligocene periods. With Hutton the Eocene is a period of erosion and elevation, but Hector's time-lapses are of brief length, and therefore of relatively little importance. It is, however, obvious that an unconformity between Cretaceous and Miocene rocks in Park's classification should be of such a marked nature as to be a conspicuous feature in all the clear sections in the districts in which the rocks are developed.

Extremely different, too, are the periods to which the main portion of the series, including at least the important coal-measures of the east coast, have been referred. Hector places these in the Cretaceo-tertiary, Hutton in the Oligocene, and Park in the Miocene.

III. Classification proposed by the Authors.

(a.) *Discussion of Waipara Gorge and Weka Pass Sections.*

(See fig. 3 and Plate VIII.)

The writers of this paper have long been conversant with these opinions, and have seen grave reason to reject them in those portions of the Dominion with which they are familiar. The doubts thus aroused caused them to visit in company the more important of the sections upon the inspection of which the classifications of the authors named were mainly based.

Of these localities, it is admitted by every one that the gorge of the Waipara River gives the most complete and satisfactory section, while that of the Weka Pass is one on which Hutton and Park have mainly relied for the demonstration of the unconformities that they have described. The third locality, the Amuri Bluff, is of importance because of the abundance of fossils contained in the lower rock-series.

The following quotations appear to us to represent the gist of previously formed opinions on the rocks shown in these sections :—

Hutton (N.Z.G.S. Rep., 1873–74, p. 44), at Waipara: "The Weka Pass stone is seen to rest on a water-worn surface of the Amuri limestone." Also, p. 48: "At Waipara the Pareora formation rests on the Trelissick group without any appearance of unconformity."

Haast (Geology Rep., 1871, p. 8): "The beds [to top of Weka Pass stone] follow in unbroken sequence—that is, they belong to the same series, and mark a well-defined period in the past history of this portion of the globe." Also, p. 16: "After the deposition of the Weka Pass beds the whole series seems to have risen to such an extent as to come under the full destructive influence of tides and currents, if not even under subaerial influence. However, the newer strata must in some instances have been deposited very soon, as the uppermost beds of the Weka Pass have not only been preserved entirely, so that no sign of denudation is visible, but the Cucullaea beds overlie them in most instances so conformably that it is impossible to detect the least difference in strike and dip."

McKay (Geol. Rep., 1874–76, p. 39): "At all points where the Weka Pass beds are overlaid by any higher beds the marly grey or green beds are the next in succession, and in many places they pass insensibly from one to the other." Geol. Rep., 1890–1, p. 102: "Although the change from the Amuri limestone to the Weka Pass stone is somewhat sudden and sufficiently clearly marked, there is not in the cross-section exposed

Panorama of Weka Pass from Crest of Mount Donald Range.

in the gorge, or along the line of strike for a mile to the north-east or south-west, or elsewhere in the district any sign of uncomformity between these beds. . . . At the lower end of the limestone gorge the Weka Pass stone is overlaid by the grey marls. The section is clear, and shows perfect conformity between the two. . . . At the junction between the lower part of the Mount Brown beds and the upper part of the grey marls a stratigraphical uncomformity is here evident enough in the section displayed."

Park (Geol. Rep., 1883, p. 33): "The sequence of the beds just enumerated is the most complete to be found in any part of New Zealand. The stratigraphy is plain and simple, being free from obscurities, and offering few points of possible disagreement." At p. 35: "At the Waipara, on the other hand, the geological record is complete, the beds following one another in one conformable sequence." At p. 22: "The Weka Pass stone passes gradually into the grey marls without any sudden change in the character of the deposits such as is seen between the Weka Pass stone and the Amuri limestone." At p. 28: "The strata at the Waipara, where the complete sequence is exposed, are quite undisturbed, following one another uniformly throughout all parts of the district. . . . I am strongly of opinion that a complete sequence of beds exists from the base of the Cretaceo-tertiary to the close of the Pareora formation."

Very similar opinions have been expressed by the geologists in regard to the series exposed in the Weka Pass. In other words, Hutton is constantly bringing evidence of unconformity between the Amuri and Weka Pass stone, and, in 1886, between the grey marls and Mount Brown beds. Haast still supports a subdued unconformity between the Weka Pass stone and the grey marls, while McKay and Hector (1890–91, p. 98) place an unconformity at the base of the Mount Brown beds only. Park, however, in 1904 (Trans. N.Z. Inst., vol. 37, p. 542) absolutely changes his position, and places an unconformity between the Weka Pass stone (Cretaceous) and the grey marls (Miocene), but states that this break is nowhere to be seen in section, although shown by the mapping. He also places an unconformity between the Mount Brown and the overlying beds, which he now calls Motunau (Pareora, Hutton).

It is certainly remarkable that such a variety of opinion should have been given in connection with a section that is so remarkably clear and free from any obscurity. As the authors are engaged in teaching this subject in the colleges of the New Zealand University, and were much perplexed by these statements and the still more conflicting results when correlations were attempted with the series in other parts of New Zealand, it was agreed to visit the Waipara and Weka Pass in company and try to arrive at a conclusion that might express the actual facts and yet perhaps be unanimous. The result, based on the stratigraphy alone, has been wholly satisfactory, and there is an unreserved agreement. For the sake of clearness, the unconformities described by different observers will be taken in order from below upwards.

Relation of Amuri Limestone to Weka Pass Stone.

1. *Hutton's Unconformity.*—The Amuri limestone is white and rubbly; the Weka Pass stone has much glauconite, and is compact. Hutton describes the proof of unconformity as consisting of pebbles of the Amuri limestone imbedded in the base of the Weka Pass stone. McKay and Park

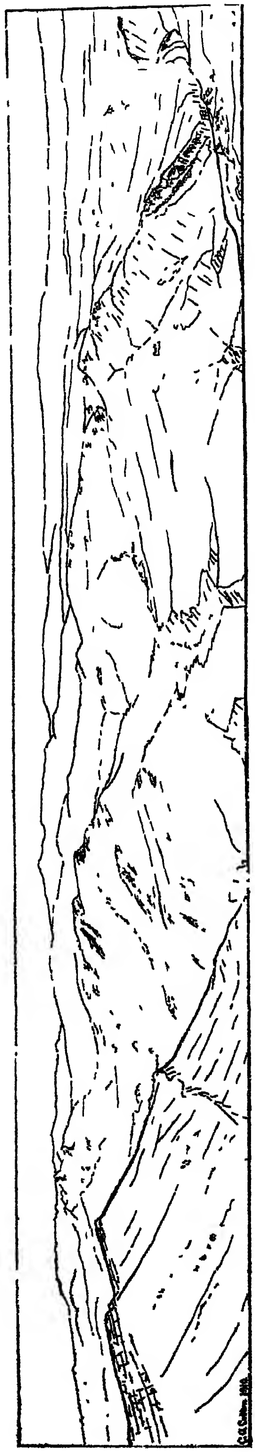


FIG. 3.—PANORAMA OF WEKA PASS FROM CREST OF MOUNT DONALD RANGE.

refer to these as phosphatic nodules. Our opinion is that the change from pure (Amuri) to glauconitic (Weka Pass) limestone does not take place throughout the mass of the rock, but interlaminations of glauconitic matter arise and separate pieces of limestone. As the conditions that control the depositions become more changed, the interlaminations of glauconitic matter become larger, and the pure limestone is reduced to nodules which appear like rolled pebbles. A similar lamination is distinct at Milburn and Clarendon. In addition to this, it is evident that the elevation of a foraminiferal limestone and its subsequent erosion followed by depression and deposition of glauconitic limestone in perfect accordance without any intervening strata would necessitate extraordinary conditions; in fact, it is almost impossible to suggest a series of conditions that would satisfactorily account for such a sequence. In this matter we agree with Hector, McKay, Haast, and Park; but differ from Hutton.

2. *Relations of Weka Pass Stone to Grey Marls.*—Very slight *unconformity of Haast*, but *break between Cretaceous and Miocene of Park.* No junction is described by either of these observers. We found one below the limestone gorge of the Waipara, as described by McKay, and found a perfect conformity. This is accentuated at the Amuri Bluff, where the Weka Pass stone is absent, and in an absolutely clear sea-cliff the Amuri limestone graduates into the grey marls to such an extent that it is impossible to say where one begins and the other ends. There is another clear section of a similar nature at the mouth of the Jed. The idea of this unconformity was based on the mapping of the district (Trans. N.Z. Inst., vol. 37, 1904, pl. 48; but compare with Geol. Rep., 1888, sketch-map opp. p. 30). We believe that the former map is totally misleading, though the latter almost represents the actual outcrops. The statement that "the Weka Pass and Amuri limestone are thrown into folds in which the Tertiaries take no part whatever" we believe to be erroneous. The actual structure is as shown in the accompanying map and diagrams (figs. 4, 5; also sections 2, 3, fig. 6), an anticline pitching sharply to the east and bringing the limestone outcrop on the east of the anticline to the level of the railway. To the north this is succeeded by a syncline pitching east and by another sharp anticline, but east of the railway-line the pitching anticline and syncline radiate from a point near the viaduct, where they die away; so that further east the north limb of the

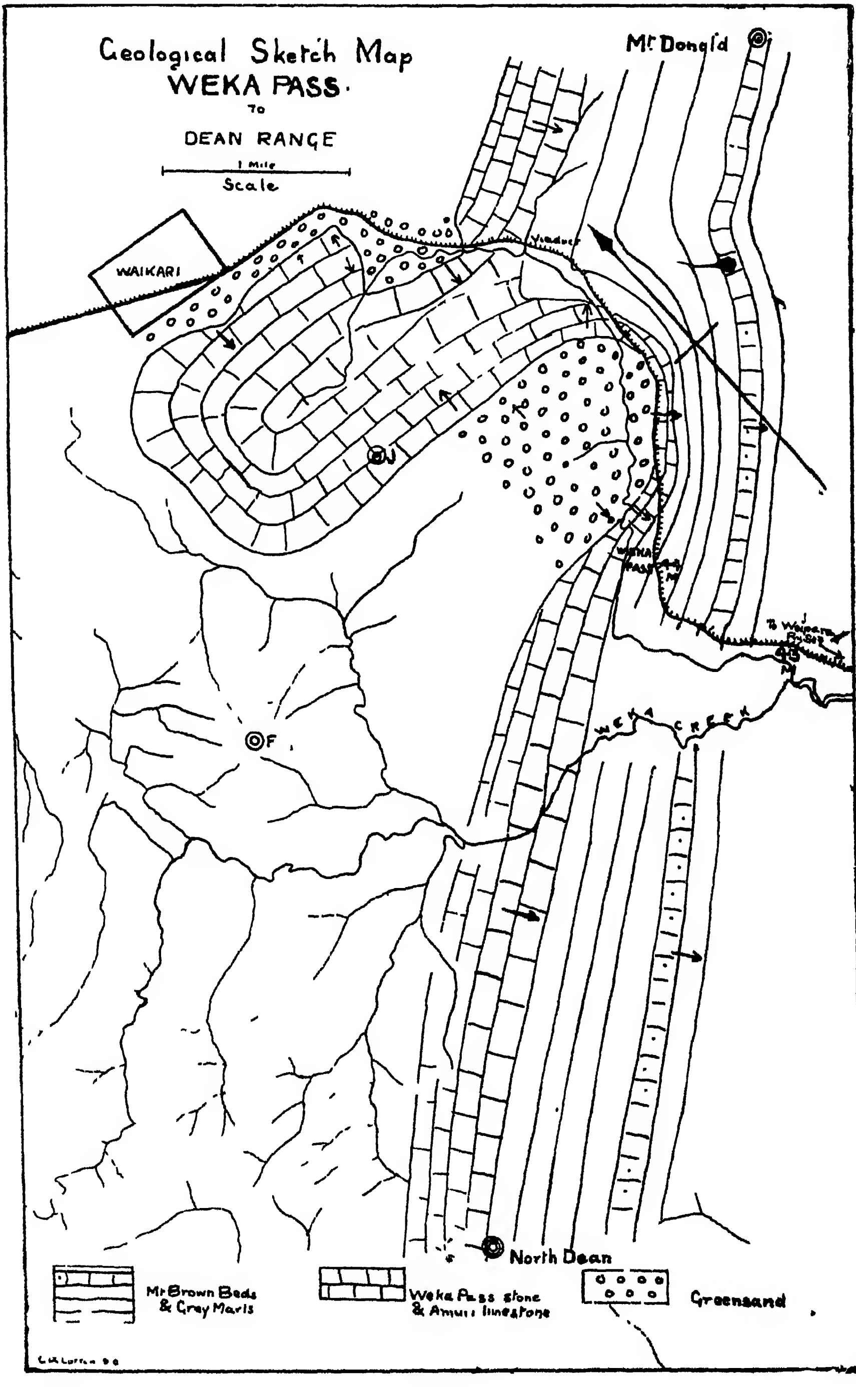

Geological Sketch Map
WEKA PASS
to
DEAN RANGE
1 Mile
Scale
Mt Donald
WAIKARI
Viaduct
J
WEKA PASS
F
WEKA CREEK
To Waipara
North Dean
Mt Brown Beds & Grey Marls
Weka Pass stone & Amuri limestone
Greensand

FIG. 4

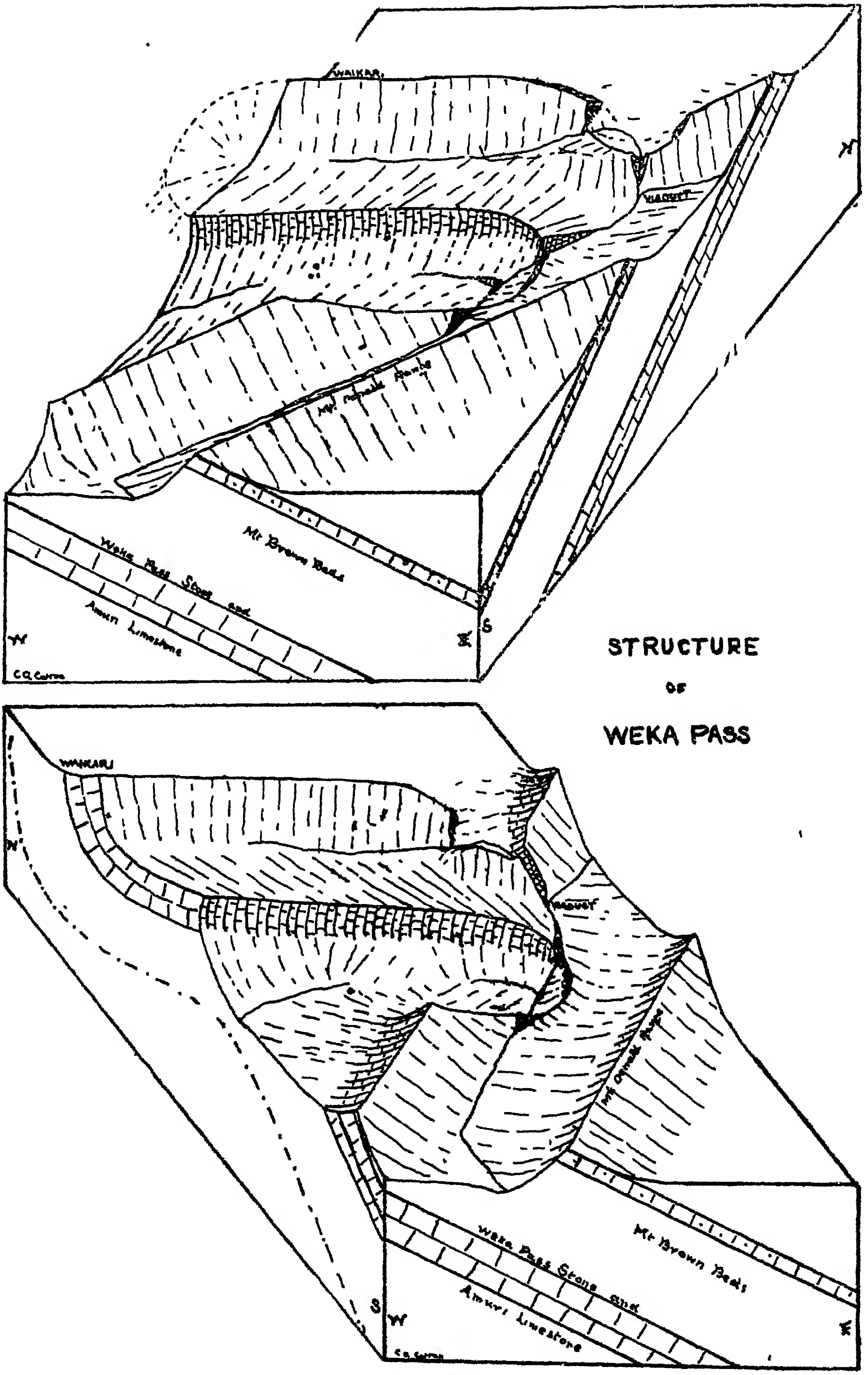

STRUCTURE
OF
WEKA PASS
WAIKARI
VIADUCT
Mt Brown Beds
Weka Pass Stone and
Amuri Limestone
C.A.Cotton

Fig. 5.

syncline or the south limb of the anticline beyond alone remain. Not only does this simple structure explain the somewhat irregular nature of the outcrops, but also the sudden bend of the Weka Pass Creek into the hard limestone, for this course we believe it followed in the upper softer beds above before it corroded its bed as low as the surface of the harder rock. In addition to this observation, there is further evidence in the parallel nature of the outcrops of the Mount Brown and Weka Pass stone between the Weka Pass and the Waipara Gorge. Standing on the summit of Mount Donald and looking southward, this is a particularly marked character. The two beds are hard, and dip approximately S.E. at an angle of from 15° to 20°. Sharp escarpments have naturally been formed, and are the dominating features of the country. They can be seen and followed with the utmost distinctness over miles of country without any bend in the strike of either being noticed. This statement is in perfect accord with the observations of McKay quoted earlier.

3. *Relation of Grey Marl to Mount Brown Beds.* — *Hector, McKay,* and *Hutton* agree on an *unconformity* here; Haast and Park have failed to observe one. Hector and McKay rely mainly on the junction of these beds exposed in the Waipara Gorge. This junction is now well exposed, owing to the formation of a road-cutting. We examined this with great care on the 6th February, 1910, and unreservedly agreed that in this clear section there is no unconformity whatever, but a gradual change from the one formation to the other. Hutton relied mainly on a railway-cutting in the Weka Pass a little south of the 44th mile-post. Here there is a clear break in the stratification. However, the beds on the two sides are of the same nature (Mount Brown beds), and the plane of union is most regular, and inclined 45°. This we believe to be a small fault, but the throw cannot be measured. Park and Hector do not mention this section.

4. *The Junction between the Mount Brown and Greta, Motunau, or Awatere Beds of Different Classifications.*—*Park* alone has described an *unconformity* here. The section on which he relies is near the 43rd milestone. The coralline sandstone (of his Mount Brown or Miocene series) that he describes as having an isolated outcrop at the south-east we found was continued without break above the sands that he refers to the Motunau or Pliocene series. At the north-west end there is no indication of uncomformity on the south-west side of the cutting to which he refers. The section here, however, is so much obscured by vegetation of many years' growth that details were not distinct. On the north-east side of the section the details are perfectly distinct, and there is a complete conformity in the series. In regard to this matter we are in agreement with all the other geologists who have examined this country.

Careful and detailed examination of all these described unconformities, made with descriptions and diagrams of previous observers in our hands, has convinced us that there is no unconformity in the Waipara and Weka Pass sections.

(*b.*) *The Amuri Bluff.*

Here McKay has described a complete conformity, but Hutton states that on the south side of the Bluff the Amuri limestone is unconformable to the Grey Marls which here overlie it to the exclusion of the Weka Pass stone. This unconformity is based on the change in dip of the two series. Our observations showed that the Grey Marls dip more and more steeply as they are followed to the west, and that the Amuri limestone does not

dip more steeply than the lower strata of the grey marl which are in contact with it. At the entrance to the Okariki Stream there is, however, a strong suggestion of an unconformity which apparently was not noticed by Hutton. Here the Amuri limestone is locally puckered in an extraordinary manner, while the Grey Marls are stratified simply. A phenomenon of a precisely similar nature is to be seen at Kaikoura, and, judging by Haast and Hutton's descriptions, in the valley of the Conway as well. At Kaikoura Hutton describes this as an unconformity.* McKay, whose opinion is indorsed by Hector, is strongly in favour of conformity.† (See fig. 6, section 1.) Boehm, who has also visited this locality, refuses to give an opinion on this matter: "Ich gestehe, dass ich nicht daruber in's Klare gekommen bin, ob der grey marl concordant oder discordant über dem Amuri limestone liegt."‡ Our opinion is that the two series are perfectly conformable, but during the folding movements to which they have been subject the plasticity of the grey marl allowed this rock to yield to the force without its whole mass becoming deformed. The hard and unyielding nature of the Amuri limestone, however, prevented anything of this nature taking place, and finally adjustment by folding was necessary. It is only locally in the most restricted sense that the Amuri limestone has been affected in this way, as is clearly seen at the Amuri Bluff, where at the north head this rock and the grey marls are displayed in perfect clearness, and are absolutely conformable. The section at the Bluff is also of extreme importance, because there the Black Grit is well developed, and this is the lowest bed of Hector's Cretaceo-tertiary. There is here certainly no unconformity separating this bed from the rocks accepted as Cretaceous by all the authors cited; and this is admitted by Hector, who states that "the further work of the Survey tended to show that the Lower Greensand formation (Cretaceous) was almost universally followed conformably by the Cretaceo-tertiary series, and that, too, in a manner which but little supported the idea of any unconformity separating the lower beds and higher beds of the two formations."§

In other respects the section at the Amuri Bluff calls for no further mention at the present time. We only wish to emphasize our opinion that here, as at the Waipara and the Weka Pass, there is a perfect conformity from the youngest to the oldest of those members of this younger series of rocks which are present.

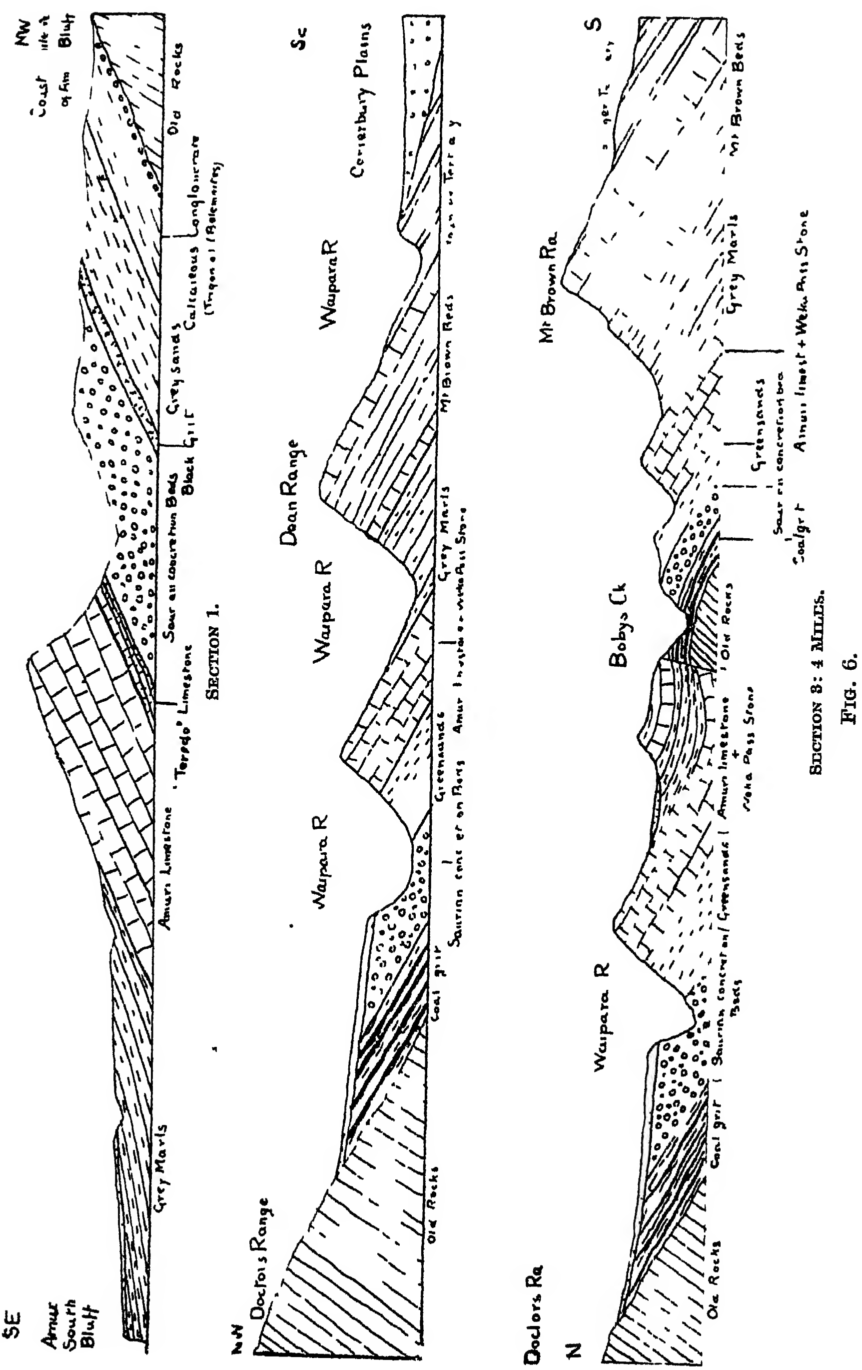
We have also been unable to find any unconformity between any members of the series of younger rocks at the mouth of the Jed River.

(c.) *Other "Cretaceous" Localities.*

There are many other localities where Cretaceous rocks have been described by one or more authors, and the existence of unconformities between them and the Cainozoic rocks has been asserted. These localities we have not visited in company, and but brief mention of them will be made here, as they have not been taken as typical.

Castle Hill (Trelissick) Basin.—This has been described by Hector, Hutton, and McKay, and unconformities have been noted by all three.

* Hutton: Q.J.G.S., 1885, p. 273.
† Geol. Rep., 1886–87, p. 74; also Hector, *loc. cit.*, p. x.
‡ Boehm: Zeit. d. Deutsch. Geolg. Gesellschaft Jahrg., 1900, p. 173.
§ Hector: Rep. Geol. Surv., 1890–91, p. li.



SECTION 1.

SECTION 3: 4 MILES.

FIG. 6.

In some cases these are founded on an incomplete examination of the district. The sequence is slightly different from that which occurs in other parts of the country. The lower part (the Waipara system of Haast) corresponds almost exactly with that at the Waipara Gorge, but the upper limestone—the equivalent of the Weka Pass stone of Hutton and the Mount Brown limestone of the Survey—is said by both Hutton and McKay to rest on the lower beds unconformably. The interpretation of the sections is, however, rendered very difficult owing to the disturbance caused by the volcanoes which broke out at the period when the limestones were being laid down, so that this unconformity may be deceptive. In any case, in those parts of the basin where the sequence is little disturbed no undoubted unconformity can be seen. Another unconformity above the limestone has been urged by the same two observers, but there seems to be no necessity for this as well. It cannot be said definitely, however, that none exists, as the beds are much disturbed by faulting, folding, and by volcanic action, and the district can hardly be regarded as a critical one for the elucidation of the Tertiary sequence. It should perhaps be noted that the section given by Hutton of the Hog's Back, which shows an undoubted unconformity between the Pareora series and the Amuri limestone, is not correct, and is apparently based on unreliable information.

Curiosity Shop Beds.—This well-known occurrence of the Tertiary series has been thoroughly dealt with by Hector and Hutton. The former, basing his conclusions on the observations and report of McKay, places an unconformity at the base of the equivalents of the Mount Brown series and over a limestone correlated with the Ototara limestone of the Survey. Hutton, however, maintained that the series was conformable from top to bottom, and after a careful examination of the locality we can see no reason whatsoever for the unconformity and agree with Hutton in his interpretation of the section.

Motunau Creek.—This locality is an important one, as it gives a complete sequence from the base of the series, with coal-beds and saurian remains, up to marls which have been classed as Upper Miocene by McKay and Lower Pliocene by Park. A careful examination of the sections so clearly exposed in the Motunau Creek reveals no unconformity, the dip and strike of the beds being constant from top to bottom, or, if any undetected variations do occur, they can only be very slight, and cannot affect the general conclusion that the sequence is conformable. The only appearance of an unconformity is suggested by the thinning-out of the Amuri limestone (the Weka Pass stone is absent in the section exposed in the creek) on going north, where it is apparently replaced by a calcareous sandstone, which is a natural transition on approaching a shore-line.

West Coast of South Island.—The coal-series of the west coast of the South Island was tentatively classed in the Cretaceous by Hector, and definitely so by Hutton. There is practically no evidence of the age of these beds, for that given by Haast has never been confirmed.* It appears that, despite the many excellent sections that are exposed, no definite evidence has yet been found of an unconformity. Lately Morgan has laid emphasis on the occurrence of pebbles of coal in a grit.† This he regards as evidence of the elevation and erosion of the coal-series before the upper

* Haast: Report of a Topograph. and Geolog. Explor. of Western Nelson, p. 106. Nelson, 1861.

† Morgan: Third Annual Rep. Geol. Surv., 1909, pp. 12, 13.

rocks were deposited. He has, however, up to the present been unable to find any stratigraphical break, and the occurrence of the coal pebbles may, in the meantime at least, not unreasonably be ascribed to contemporaneous erosion, or even in many cases to the inclusion of wood-fragments in the sediment.

The coal-measures of Pakawau have been placed by Hutton in the Cretaceous. This is apparently based on the occurrence of fossil plants and on the nature of the coal. One of us has carefully examined the ground, and has formed the opinion that in that locality no unconformity separates the coal-measures from the overlying rocks of admitted Cainozoic age. This is in accord with the opinion of Park, who in 1890 classed no beds but the Cretaceo-tertiary as lying between the glacial matter and Palaeozoic strata.* Cox, in 1883, had described a Lower Greensand formation as lying below the Cretaceo-tertiary series, but makes no mention of a break.†

Poverty Bay.—In the Poverty Bay district a complete series of Cretaceous and Tertiary rocks has been described by McKay.‡ This district has, however, lately been worked in detail by Adams,§ who classed all the rocks of Upper Miocene age, stating that no marked unconformity was observed between any of its members. One of us has examined the sections in this area in great detail, and is positive that no unconformity was shown in the many miles of continuous sections displayed.

Shag Point.—Here Hutton,‖ Haast,¶ and Park** have described an unconformity, but in different localities. McKay,†† in 1886, showed clearly that Hutton's and Haast's break was really due to a fault, as stated previously by Cox. The unconformity referred to by Park is a matter of inference, and is placed in the middle of the Shag Estuary, where no rocks crop out at the surface. One of us visited this district, but was not able to go over the ground in any detail. No evidence of an unconformity was found as a result of the examination made on this occasion. The rocks are here somewhat more folded than usual, and it is natural to hesitate to allow the presence of an unconformity until the effects of faulting and folding have been fully set out. This was done by McKay, and, we believe, with considerable success in showing that such structural features satisfactorily accounted for the position of the various outcrops.

(*d.*) *Oamaru District.*

The variety of opinion in regard to the relation of the rock-series in the very clear sections of North Canterbury becomes still more confusing when attempts are made to correlate with the Canterbury series the younger rock-outcrops occurring elsewhere (see fig. 7). This is particularly true of Oamaru, where there is a clear series with quartz gravels at the base and marly shell beds at the top. The different members of the series are shown in the accompanying diagrams. In this series Hector inserted two

* Park: Rep. Geol. Surv., 1890, p. 229.
† Cox: Rep. Geol. Surv., 1883, p. 71.
‡ McKay: Rep. Geol. Surv., 1886, p. 192, map; also Geol. Explor., 1900–1, p. 23.
§ J. H. Adams: N.Z. Geol. Surv. Bull. No. 9 (n.s.), p. 12.
‖ Hutton: Geol. of Otago, 1875, p. 46.
¶ Haast: Geol. Rep. 1873–74, p. 24.
** Park: Geol. of New Zealand, 1910, p. 116.
†† McKay: Geol. Rep., 1886, p. 22.

unconformities, above and below the Hutchinson Quarry beds, which rest on the well-known Oamaru stone. The Hutchinson Quarry beds are greensands, with many brachiopods and other fossils. They are generally taken as equivalent to the Mount Brown beds.

The Awamoa beds are more marly, and undoubtedly rest on the Hutchinson Quarry beds. They contain an abundance of forms of littoral *Mollusca*. The series is particularly well exposed at the rifle-butts south

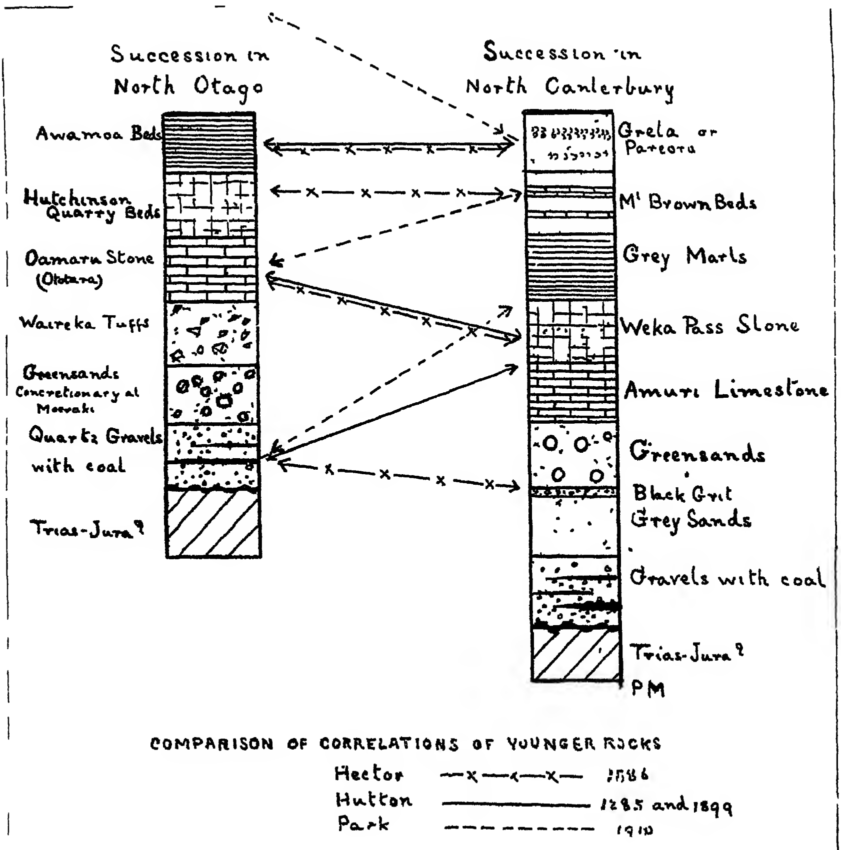


FIG. 7.

of Oamaru, and there the conformable nature of the series is distinct, as noticed by Park. Another junction between the Awamoa beds and the thin development of Hutchinson Quarry beds is exposed at the north end of All Day Bay, and here there is a conformity, as was admitted by McKay,* who in the same report† states that the Miocene beds (Awamoa) pass gradually into the Hutchinson Quarry beds, and thus he admits the conformable nature of the whole series.

* Geol. Rep., 1886, p. 236. † *Loc cit.*, p. 235.

One of us has spent much time in this district, and has made a careful inspection of these and other sections (see fig. 8), and is positive that the different members of the series are perfectly conformable in all the sections that he has visited. Even if, as is reasonable, the series be recognized as completely conformable, the correlation of the strata allows room for a difference of opinion when they are referred to the typical occurrences in North Canterbury. How great these differences of opinion are may be seen from the accompanying table (fig. 7). In our opinion, it is perfectly reasonable and satisfactory to correlate the groups that are lithologically similar throughout. Thus the Oamaru stone and the Amuri limestone are similar, and should be correlated. So with the concretionary greensands and the Moeraki boulder-beds, the quartz grits and the basal conglomerate, the Weka Pass stone and the Hutchinson Quarry beds. The full reasons for this suggested correlation will be explained later.

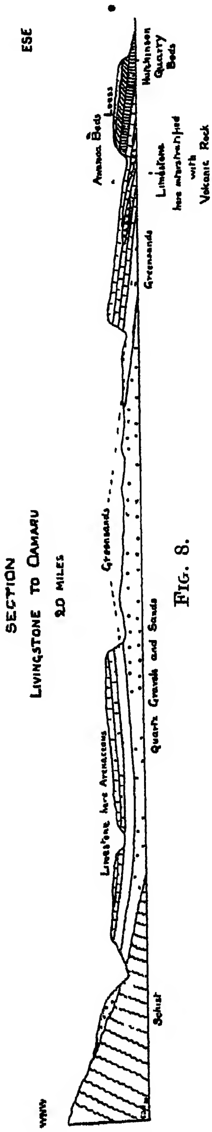


FIG. 8.

It is of importance to note that Boehm is unable to accept the separation of the Oamaru stone as Cretaceo-tertiary from the Hutchinson Quarry as Eocene. He says that the only distinction he can discover is that one formation is richer in fossils than the other, and that at Oamaru he can find no evidence in favour of placing the Oamaru stone in a Cretaceo-tertiary class.*

Park has made much of a suggested distinction between two limestone series at Oamaru.† The only place where these two limestones are said to occur in the same section is at Kakanui North Head, and there they are separated by a volcanic rock only. Since the breccia at Oamaru and numerous sections in its neighbourhood show clearly that volcanic action was prevalent during the deposition of the limestone, this section is not convincing. McKay in his last report on the district omits all mention of two limestones, and one of us who has closely examined the district has quite failed to find any evidence of the presence of more than one limestone.

This limestone is commonly known as the Oamaru stone, but in geological reports it is called in almost every case the Ototara series. While too much space would be taken in stating the stratigraphy in detail, the writers are of opinion that there is but one limestone formation in the district, and that its character becomes in general less pure and gradually more arenaceous as the old shore, usually to the west, is approached.

This point of view is strongly supported by Boehm, who specifically states that the rock at the Devil's Bridge, the upper limestone at Kakanui,

* Boehm: Zeit. d. Deutsch. Geolg. Gesellschaft Jahrg., 1900, p. 175.
† Park: Trans. N.Z. Inst., 1904, vol. 37, p. 504 *et seq.*

and the limestone at Totara are all exactly the same series.* McKay also correlates the limestone at the Kakanui with that at Totara.†

(*e.*) *West Coast of the North Island.*

The series of Cainozoic rocks on the western side of the North Island from Kawhia to Palmerston is lying almost horizontally. There appears to be no unconformity throughout, and there is the same order of deposits as found in North Canterbury, Nelson, and elsewhere. The lower members of the series are, however, exposed in the north only as far south as Taumarunui. They have been divided into different series from the Cretaceous to the Pliocene,‡ but on general principles only. Bell§ regards them as Tertiary, and mainly Miocene; Park|| as mainly Pliocene, though the lower members are classed as Miocene. The most noticeable point about the development of the rocks in this area is the great thickness of the upper members of the series: the grey marls are probably not less than 2,000 ft. thick.

(*f.*) *North Auckland.*

Recently a careful survey has been made by Clarke of the Whangaroa district.¶ The Kaeo series as there described is formed of the younger rocks. It consists of conglomerates, tuffs, concretionary shales, massive limestones, greensands, and calcareous sandstones. It is, however, doubtful whether this is a conformable series. If it is so, it strongly resembles the series developed in North Canterbury.

(*g.*) *Waitemata.*

[Contributed by E. DE C. CLARKE.]

As elsewhere in New Zealand, the succession and relationships of the later sedimentary rocks immediately to the south and east of Auckland have been interpreted in more than one way. Most of the interpretations have probably attracted little notice. In his widely known "Summary of the Geology of New Zealand,"** however, Hutton gives a section illustrating his conception of the relation between the representatives of his Pareora and Oamaru systems between the Wairoa River and Howick. He gives no detailed account of the section beyond saying that it "is hard to understand but is quite clear. The Pareora system has been shown by Mr. Cox and myself to lie quite unconformably on the Oamaru system in the Auckland Province." In an earlier paper†† he says, "At Turanga Creek we find the water-worn surface [of the Papakura series] covered by a series of yellow clays and sandstones which form part of the Waitemata series of Professor Hochstetter." He also gives a section (*loc. cit.*, pl. xxvii, sec. iv) with which the section given in Q.J.G.S. agrees in essentials.

General.—After a complete examination of the district, and specially of critical localities, the author has come to the conclusion that the following

* Boehm: Zeit. d. Deutsch. Geolg. Gesellschaft Jahrg., 1900, p. 174.
† McKay: Geol. Rep., 1883–84, p. 63.
‡ Park: Geol. Rep., 1886–87, p. 180.
§ Bell: Annual Rep. Geol. Surv., 1910, p. 6.
|| Park: N.Z. Geology.
¶ Bell and Clarke: N.Z. Geol. Surv. Bull. No. 8 (n.s.), 1909, p. 47.
** Q.J.G.S., 1885, vol. 41, pp. 209, 210.
†† Trans. N.Z. Inst., vol. 3 (1870), p. 247.

account gives the most correct interpretation of its stratigraphical relations.

The old rocks of the Maitai series—possibly of early Mesozoic age—form the core of the Maraetai Hills and reach the shores of the Waitemata (Auckland) Harbour near Maraetai. Skirting these hills, and lying unconformably on the older rocks, are various sedimentaries—conglome-

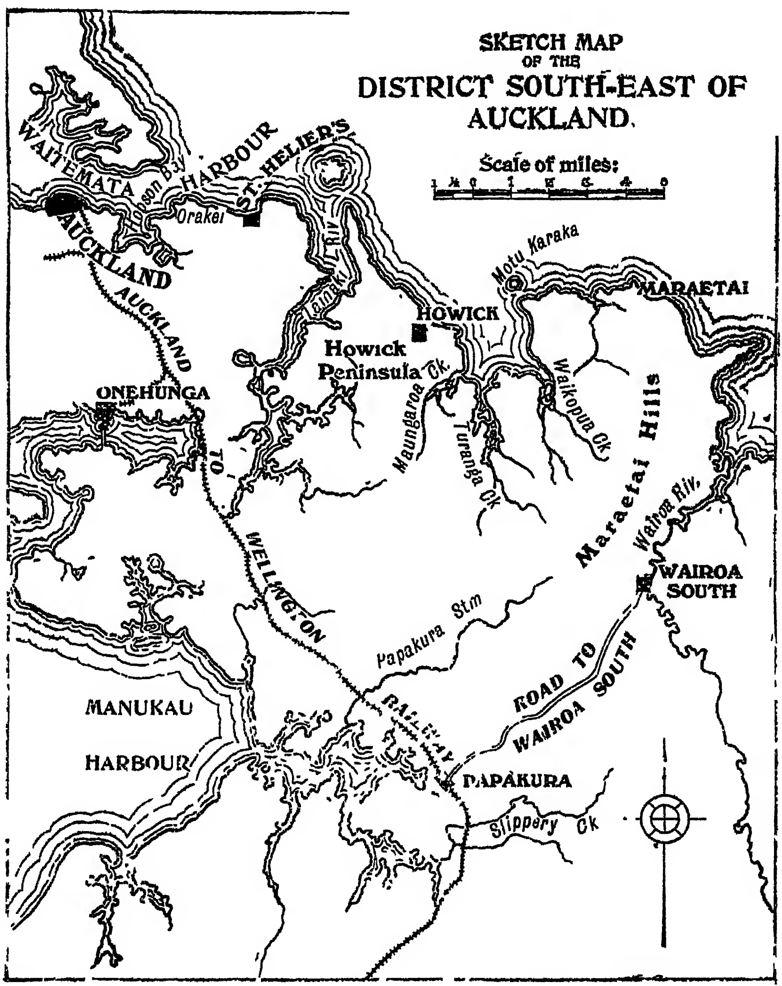


FIG. 9.

rates, sandstones, clays, and limestones—which are typically exposed in Slippery Creek, near Papakura, and to which the name of Papakura series was given by Hochstetter. The characteristic beds of the Papakura series have since Hochstetter's time been found to extend along the flanks of the hills in a northerly direction at least as far as Waikopua Creek, where limestone resembling that in Slippery Creek was found by Park.

The beds of sandstone and clay with interbedded volcanic grits exposed round the shores of the Waitemata Harbour have been known since the days of Hochstetter as the Waitemata series.

The Waitemata series is unconformably overlain by the lava-flows and fragmental volcanic material from the volcanic vents of the Auckland Isthmus, and at Panmure by later sedimentary deposits.

All observers appear to agree that between Maraetai and Turanga Creek rocks belonging to the Papakura series are represented, while the sedimentaries between Turanga Creek and Auckland are unanimously called Waitematas. Near Turanga Creek, therefore, the contact between the two series, if they are distinct, must occur.

Cox, in a paper "On certain Points Connected with the Geology of the Auckland District,"* gives a section from Maraetai to Tamaki West, in which he shows the "Maitai slates" overlain by the following sequence of rocks: "(*b*) Calcareous sandstone, (*c*) clay marls, (*d*) concretionary tufaceous sandstone, (*e*) clay marls, (*f*) concretionary tufaceous sandstone, (*g*) bedded sandstones and clay marls, (*h*) plastic clays and sands." He says that either a direct sequence occurs from (*b*) to the Orakei Bay beds, with a possible unconformity between (*d*) or (*f*) and the Howick beds—presumably (*e*), (*g*), or (*h*)—or else that the beds forming Howick Peninsula are unconformably younger than both (*d*) or (*e*) and than the beds found between Tamaki West Head and Orakei Bay. While he regarded the latter view as the more probable, he considered that stratigraphical evidence favoured the former view. Hutton's views have already been summarized. Park (with whom McKay† agrees in this matter) in two papers‡ affirms the conformity of the Waitemata and Papakura series east of Howick, considering that the irregular overlap taken as evidence of unconformity by Hutton and Cox was due to unequal erosion of hard and soft beds.

In his paper on "The Volcanic Beds of the Waitemata Series" Fox§ remarks (p. 485) that from the Papakura limestone to the highest Waitemata sandstones the series apparently has no break.

The evidence for unconformity between the Waitematas and the Papakuras appears to depend on (1) the relation between the series as seen near Turanga Creek; (2) the relation between the series as seen in the cliffs between Howick and Maraetai.

As regards (1), the writer has followed the sequence from the so-called Turanga greensands (which are volcanic grits)‖ which Hutton regards as part of the Papakura series to the undoubted Waitematas at Howick, and after mapping all the observed strikes and dips¶ can find no evidence of unconformity.

As regards (2), passing along the shore-line from Motu Karaka towards Maraetai, alternating sandstones and clays, in places dipping steeply, in others almost horizontal, are seen to be quite unconformably overlain near the top of the low cliffs by a soft clay showing little or no bedding. In the upper part of this clay is a well-defined horizontal seam, about 6 in.

* Rep. Geol. Surv., during 1881.
† Rep. Geol. Surv., during 1887–88, p. 40.
‡ Rep. Geol. Surv., during 1885, p. 136, and Trans. N.Z. Inst., vol. 22, p. 391.
§ Trans. N.Z. Inst., vol. 34, p. 485.
‖ Fox: Trans. N.Z. Inst., vol. 34, p. 485.
¶ Too numerous to place on the rough sketch-map accompanying this paper.

thick, which may be traced for a considerable distance along the cliffs. This band appears to be a very impure pumiceous earth.

According to Hutton, the lowest beds seen in the section described above are to be classed with the Papakuras, the upper beds with the Waitematas. But the lower beds show a very close resemblance to the typical Waitematas as seen near Howick, at the other side of the Turanga Creek, and may be traced at intervals round the shores of Turanga Creek until they are found to pass into the upper rocks which Hutton describes as Waitematas, and which he says unconformably overlie the greensands (belonging also to the Papakura series) at Turanga Creek. On the other hand, the uppermost beds seen in the cliffs between Motu Karaka and Maraetai are quite distinct lithologically from the Waitematas as developed elsewhere.

Stratigraphically and lithologically, therefore, there seems no reason to regard the lower beds between Motu Karaka and Maraetai as other than Waitematas, and lithologically there is good reason to regard the upper beds as distinct from the Waitematas, and younger.

It may be of interest to note that at Slippery Creek, while the bed of the creek is occupied by the fossiliferous limestone and conglomerate of the Papakura series, the upper parts of the hills bordering the stream are composed of alternating sandstones and clays showing a close resemblance to the typical Waitemata beds. No evidence of unconformity between the upper and lower beds just described could be found by the writer.

Stratigraphical evidence too detailed to be given in this paper has been collected by the writer which shows that there is little or no vertical difference between the lowest beds of the Waitematas and the lowest beds of the Papakuras.

In conclusion, therefore, it seems highly probable that the Waitemata and Papakura series are part of one conformable series The differences between the typical beds of the two series would, of course, be due to differences in conditions of deposition.

IV. DEPOSITION OF ROCKS OF THE SERIES.

(a.) *General.*

A careful consideration of the stratification of these younger rocks, a brief summary of which has been given in the preceding pages, has impressed the writers with the belief that there is a single stratigraphical series of younger rocks in New Zealand, and that this series is of very general development and has a remarkably similar lithological succession in all the localities. There are, however, some problems of considerable difficulty that require solution if this statement be adopted. Briefly stated, the main problem is of this nature. At the Waipara Gorge, Amuri Bluff, and the Malvern Hills, fossils that have decidedly Cretaceous affinities are found in the lowest rocks. The most important of these are *Belemnites australis* Phillips, *Conchothyra parasitica* McCoy, *Trigonia costata* Hector, *Trigonia sulcata* Hector, *Inoceramus haasti* Hochstetter, as well as a considerable number of species of pythonomorphs and sauropterygians. In the middle beds (Mount Brown) the *Mollusca* have a definitely Cainozoic appearance, and 20 per cent. belong to Recent species. In the highest beds 60 per cent. (Hutton) or 71 per cent. (Park) belong to Recent species. Though it is not here intended to lay great emphasis on the percentage

of Recent species, these figures are quoted to show the great palaeontological difference between the lowest and the highest beds. So great is this difference that it is natural to look for breaks in the stratigraphical sequence, and the temptation is naturally great to lay emphasis on any slight local irregularity in the stratigraphy and to magnify it into an unconformity. A consideration of this difference perhaps causes one to demand from an observer who holds to the idea of a conformable sequence a special explanation of the rapid faunal change, since the whole series as developed in North Canterbury is not more than 3,000 ft. thick.

(*b.*) *Explanation of Rapid Change of Life-forms.*

We believe that this explanation is to be found in these three considerations: (1) A possible isolation of New Zealand during the late Mesozoic; (2) a possible lingering of archaic types; (3) the very slow rate at which the deposits accumulated.

(1.) *Isolation.*

Evidence as to the previous isolation of the eastern coast-line of New Zealand is somewhat conjectural. It is, however, certain that in the middle Mesozoic great rock-movements were in progress, and the early Mesozoic rocks of New Zealand were folded and elevated into mountain-ranges of great size. So important was this movement in New Zealand that it is reasonable to inquire whether it extended beyond the boundaries of the present land. It is then found that to the north the rocks of New Caledonia of early Mesozoic age are also folded. In the south the quartz gravels of the lowest members of the series of younger rocks in Campbell Island were evidently derived from folded and metamorphic rocks similar to those of Otago. There is no definite evidence of further extension, for the Beacon sandstone of South Victoria Land can hardly be cited in this connection. If the New Zealand shore-line at that time (the close of the Mesozoic) extended from very low to high latitudes a measure of isolation would be thus obtained. It is noteworthy that in the folded and highly eroded rocks of early and middle Mesozoic age marine reptiles were numerous. *Trigonia*, *Inoceramus*, and *Belemnites* were well represented; so that in regard to these organisms at least there is a suggestion that during the great interval throughout which immense rock foldings and erosion were in progress the fauna of the coast-line suffered but little from the competition of new and more vigorous organisms.

(2.) *An Archaic Fauna.*

It is well known that at the present day many forms long extinct in Europe and America linger and maintain an existence in the south-west Pacific. The *Trigonia* of Australia, *Ceratodus*, *Sphenodon*, and such genera as *Struthiolaria* are, of course, examples, and it is possible that owing to causes apart from isolation many Mesozoic forms had survived in New Zealand after they had become extinct elsewhere.

(3.) *Slow Rate of Deposition.*

(i.) *Conglomerates.*—We are inclined to ascribe much of the advance in the fauna to the mere lapse of time. It is true that the total thickness of the strata is not more than 3,000–3,500 ft. at Waipara, where all the strata are present; but it is also known that nearly every member of the series has a thicker development elsewhere—to take a single example, the bottom hundred feet of sands and gravels is represented by 7,000 ft. of

gravels in Westland. It is also true that the greater part of the series was deposited on a slowly subsiding sea-floor, and was derived from a slowly subsiding land on which all the stream-grades were thus being gradually reduced, and most of the material was doubtless utilized in filling up previously eroded valleys. At the same time the area from which sediment could be derived was constantly being reduced. A more detailed description of the different strata is, however, necessary in order that the slow rate of deposition should be fully realized.

The basal gravels are, as previously stated, 7,000 ft. thick in Westland. They are certainly more than 1,000 ft. thick near Cape Farewell, and perhaps 3,000 ft. thick at Shag Point. This thickness points to a considerable lapse of time In most localities where they are relatively thin the component pebbles show evidence of great and prolonged attrition. This is most marked in Otago, where the gravels are composed almost wholly of quartz pebbles, and they are unquestionably derived from rocks of mica-schist. The rivers that flow from the schist at the present time carry down schist pebbles amongst which are a few of quartz. A great amount of attrition of the schist and a gradual survival of the hard quartz pebbles would be necessary before the change from the schist pebbles to a quartz gravel would result. This is equivalent to the statement that the rivers supplied material more slowly, and that it was subject to most prolonged attrition on the beaches before it was screened by a new supply. The lowest stratum, therefore, by its nature or by its thickness indicates that much time elapsed during its deposition.

(ii.) *The Coals.*—Interstratified with these conglomerates there are in many places beds of coal which are sometimes of great thickness. Those certainly indicate a slow rate of deposition, and imply long periods of nearly stationary conditions separating the periods of more rapid depression.

As the depression proceeded the area of land must have been greatly decreased, and this satisfactorily explains why in some localities an arenaceous limestone rests directly on the eroded surface of the older rocks. This is the case at Kawhia, and on the Gouland Downs in the west of the Nelson Province. The search for geological indication of the presence of coal-seams has perhaps more than any other reason been the assignable cause for the close examination to which the New Zealand Cainozoic rocks have been submitted. In all places where coal has been found in these rocks it has been near the base of the series, interstratified with the conglomerates. It is, however, of local extent, of very variable thickness, of variable composition, and occurs at very different levels. The fossil *Mollusca* associated with the coal in different places are, however, distinctly different. This has been the reason for assigning the seams to very different ages. Hector classed some in the Cretaceous, but the greater part in the Cretaceo-tertiary at the horizon of the black grit. Hutton considered several coals of Cretaceous age, others Oligocene, and some Miocene, in each case forming the base of the younger series of rocks in the districts where they occur.

Not only have they been classed in various ages by different observers, but the same observer has placed them in very different ages in different publications, and the whole subject of the coal-seams has thus become of a complex and confusing nature. To illustrate this it is only necessary to refer to the following works of Park in reference to New Zealand coals:—

"The Extent and Duration of Workable Coal in New Zealand" (Park, Trans. N.Z. Inst., vol. 21, p. 327, 1889): "The workable coals of New

Zealand are all of the same age." "At the base of the group with a Tertiary facies" (p. 325).

"Notes on the Coalfields of New Zealand" (Proc. Inst. Min. and Met., vol. 8, 1899, p. 148): "All the workable seams of coal are found in measures of Lower Eocene age." "Coal never has been, and never will be, found below Amuri limestone" (p. 150).

"Age and Relations of New Zealand Coalfields" (Trans. N.Z. Inst., vol. 36, pp. 411, 418, 1904): CRETACEOUS COALS (below Amuri limestone): WAIPARA SERIES—Pakawau, Mokihinui, Westport, Greymouth, Malvern Hills, Shag Point. MIOCENE: OAMARU SERIES—All the other coal-seams, of which seventeen are enumerated.

Proceedings N.Z. Inst., 1909, p. 59: The Green Island Coalfield is classed as Mesozoic.

"Geology of New Zealand," 1910, p. 293: UPPER CRETACEOUS: WAIPARA—Shag Point, Kaitangata, Malvern Hills, Kawakawa, Hikurangi, Ngunguru. WAIMANGAROA SERIES: EOCENE—Grey, Paparoa, Westport, Mokihinui, Pakawau. OAMARU SERIES: MIOCENE—Taupiri, Waipa, Mokau, West Wanganui, Inangahua, Mount Somers, Kakahu, Waihao, Ngapara, Waikouaiti, Green Island, Forest Hill, Nightcaps.

Thus, to take a single example, he has classed the Kaitangata coal as Lower Tertiary in 1888, Lower Eocene in 1899, Miocene in 1903, and Cretaceous in 1910.

Our observations have led us to the opinion that the coal is always at the base of that development of the series of younger rocks that happens to be present in any district. Since, owing to the great overlapping of the higher beds of this series, the base in any locality may be of any age between the Cretaceous and the Miocene, it is evident that the coal in particular places may be in any part of the Eocene, Oligocene, and perhaps occasionally Miocene system. It is therefore, in general, useless to classify the fossils and assign the shell-bearing strata to any definite period as a preliminary to a search for coal. It is only necessary to determine the depth of the base of the series, for it is there that coal may be found, whatever the age of the base of the series in that locality may be. It has been recognized by all authorities that individual coal-seams are not widely extended, and the frequent presence of quartz or other pebbles in them suggests detrital origin. It is therefore evident that general principles cannot here be used in predicting the occurrence of possible coal-seams. Prospecting in each separate locality is necessary, for detailed stratigraphical methods are in the main useless.

The opinion that is here expressed is strongly supported by the acknowledged absence of seams of coal in any horizon above the basal conglomerate in any section. If coals had been formed in unconformable series, it is not unreasonable to suppose that seams would be found in some localities in two different formations at different levels. This has not yet been found.

(iii.) *Greensands.*—The greensands at the Waipara and Amuri Bluff were apparently deposited under somewhat exceptional conditions. Though containing little or no pyrite, they liberate large quantities of sulphuretted hydrogen from the natural exposures in cliffs, and in many places there is an efflorescence of sulphur formed on the surface of the sandstone in some quantity.

The associated grey and white sands are also almost entirely formed of quartz, and the same remarks apply to them. The greensands are of

great thickness in the Waipara, and at Amuri Bluff 600 ft. We are not yet fully acquainted with the conditions under which greensand is formed, but the latest information shows that it is deposited near a steep coast where the water is particularly clear and perhaps 500 fathoms deep.* Such conditions evidently favour slow accumulation, and this idea is supported by the abundance of sharks' teeth in the greensand in many localities.

(iv.) *Limestones*.—The limestones vary much in thickness and in nature. The limestone at the Amuri Bluff is formed mainly of isolated chambers of *Globigerina*. It is here little more than a chalk. At other places the larger species that live on the sea-floor are more prominent. This is very noticeable in the more sandy varieties at Dunedin, and still more conspicuously at the Mokau, where the limestone contains also an abundance of the remains of the calcareous alga *Lithothamnium*. At Oamaru the building-stone consists mainly of plates of echinoderms, with *Polyzoa* and *Foraminifera*. Near Cape Farewell coral is the chief organism in it. The deposition of the limestone must represent a considerable lapse of time, for at Amuri Bluff it is 650 ft. thick, and its nature there shows that it formed with extreme slowness.

In all places it is uncontaminated with sediment, except quartz-grains. Its wide occurrence and penetration into many mountain-gorges shows how much of the present land-area was submerged at this time.

Above, as below, the limestone passes in many places into a greensand, but this upper stratum is relatively thin when compared with the lower one, and this, of course, suggests that the upward movement was more rapid than the downward movements.

The grey marls are very thick in some places, though it is quite often the case that they have been eroded off the surface of the limestone. Their absence in the southern part of the South Island is perhaps to be explained in this way, though it is quite possible that they were never deposited in that part of the country. The grey marl consists largely of minute scales of mica, though these are mixed with much calcareous matter.

The Mount Brown and Pareora beds that lie on the grey marls are relatively coarse detrital formations, and may have been deposited much more rapidly than the lower beds of the series.

Taking the series as a whole, we think that the time required for its deposition was sufficiently great to allow of considerable faunal change to take place, and specially when a possible previous isolation is borne in mind. We regard it as almost sufficient in itself to account for the important differences between the fauna of the lowest and highest members of this conformable sequence.

V. CORRELATION OF MEMBERS OF THE SERIES.

As previously stated, we believe that there is complete evidence of stratigraphical conformity of the rock-series here described. It is, however, a fact that the lowest member of the series in some localities, such as Waipara and Amuri Bluff, is much older than that of Kawhia and of Oamaru (Livingstone). This has always appeared to justify the division of the series into different geological systems, which was based on the difference in faunal characters of the various members of the series at Waipara, and supported by the stratigraphical breaks described in the series by different

* Murray and Lee.

geologists. We believe that this occurrence of a younger fauna in the basement beds in some districts than in others is due simply to overlapping. This, however, is difficult to prove, for earth-movements that have occurred since the deposition of these rocks have greatly altered the relative levels of different portions of the country, so that it is now difficult, if not impossible, to restore the early Cainozoic relief.

The disposition of the Cainozoic series shows quite clearly that the relief was then highly varied, and, if that was the case, overlapping must have taken place to a great extent in a series which in some places was 3,000 ft., in others perhaps 10,000 ft. thick, and deposited during a movement of depression that was more rapid than the rate of deposition.

This creates great difficulties in the way of all attempts to correlate the members of the rock-series as developed in different districts, for the relief of the land before depression had been so great, and the movement of depression was so much more rapid than deposition, that limestones and conglomerates were in the middle of the period being deposited within a comparatively short distance from one another. This difficulty is particularly marked because the lowest rocks are usually unfossiliferous.

While great difficulties arise for these reasons in all attempts to correlate the basal conglomerates, there is not the same trouble in correlating other members of the series. This is particularly true of the limestones. The nature of this member of the series proves that it was deposited at the time of maximum depression, when some of the areas at least were covered by deep water, and the area of the land-surface was so decreased that little sediment was derived from it, and in many places calcareous conglomerates were deposited on the very shore-line. The differences in the limestone in different localities have already been described, but it is necessary to state that the variations are found in detail only. The fact that where a complete series is developed the limestone always occupies the same position strongly supports the correlation of the limestones throughout the series.* This is the correlation adopted by Hector, and almost by Hutton, except that he placed the Amuri limestone in a lower unconformable series. It is wholly opposed to the classification of Park, who correlates the great limestone formation throughout the country with the calcareous knobbly conglomerate of Mount Brown. From this we wholly differ, for the palaeontological evidence upon which it is based is far from complete, and can be interpreted in very different ways. The correlation is mainly based upon the resemblance between the fossils collected by him at Mount Donald (Mount Brown beds) and those of the Black Point beds, which are lower than the limestone in this locality; and, again, the similarity of fossils in these beds to those in the Awamoa beds, which lie over the Oamaru stone, appears to be the reason for suggesting that a second bed of limestone—Waitaki stone—should rest on the Awamoa beds. It is also asserted that McKay and Hector always agreed that the Pareora fauna lay below the Waitaki stone.† This appears to be an error, for in Hector's Handbook the Pareora and Awamoa beds are placed in the Miocene, the Hutchinson ~~Quarry beds~~ in the Eocene, and the Ototara series (Oamaru and Waitaki stone of Park) in the Cretaceo-tertiary. When this similarity of fossil

* See T. C. Chamberlain: "Diastrophism as the Ultimate Basis of Correlation ("Journal of Geology," vol. 17, 1909, p. 685).

† Trans. N.Z. Inst., vol. 37, p. 504, 1905.

fauna is closely questioned doubts are at once raised as to the correctness of inference drawn from it.

Thus, of the twenty-eight species of Awamoa molluscs listed by Park* only fourteen occur in the list of thirty-six species recorded in the Mount Brown beds,† and eleven of his twenty species at Pareora Again, eight of these Pareora‡ species are listed in the twenty-eight of the Awamoa, and eleven of the twenty occur in the Black Point beds, while thirteen of the twenty-eight Awamoa fossils in the Black Point and eleven of the twenty-three Hampden Beach fossils are found in the Black Point beds. So that when reduced to actual figures these lists do not show any special resemblances. In nearly every case about 50 per cent. of the species in one list are found in other lists. It is certainly true that far more complete collections are required before palaeontology can be used as a basis for forming an opinion as to the exact stratigraphical position of any of these beds. When applied to the Waitaki and Oamaru limestone of Park, palaeontology is still less satisfactory. Thus, of four species stated§ as distinctive of the Waitaki stone three are quoted as found in the Oamaru stone. Again, the Oamaru stone near the old Miocene shore-line is said to "gradually merge into a yellowish-brown calcareous sandstone containing the scattered remains of huge echinoderms."‖ The Waitaki stone as it approaches the old shore-lines is "represented by the band of yellowish-brown calcareous sandstone with *Meoma crawfordi*."‖ Since, as before stated, Boehm did not distinguish between the two limestones, and since in no place can two limestones be seen in the same section except at Kakanui, where volcanic matter is intercalated, even in this district, where limestone is very generally developed and nearly always seen in exposed sections, it appears unreasonable to attempt to maintain the presence of two limestone beds.

The fauna throughout the various shell-beds, as already stated, maintains a general resemblance whether beneath or above the limestone, which is seldom more than 50 ft. thick. This merely shows that in this area, which was marginal during the deepest depression, little change took place in the littoral fauna during the deposition of the limestone. Greensands occur below the limestone at Maerewhenua, and above it at the Oamaru rifle-butts, Hutchinson's Quarry, and Deborah Railway-station. In the three last named the brachiopods are almost solely large *Magellanias;* in the former, smaller species and *Bouchardias*. It is not desired to insist upon this difference, for it may be due to a difference in station, but it does at least suggest hesitation in correlating these greensands, as is done by Park.

We are, however, in complete agreement with Park in his belief that there are no unconformities other than those of an interformational nature associated with volcanic outbursts in the Oamaru district. The unconformities supposed to separate the Miocene, Eocene, and Cretaceo-tertiary of Hector, and the Oamaru and Pareora systems of Hutton, were found not to exist. On the other hand, clear interformational unconformities are to be seen at Hutchinson's Quarry and in many places at Oamaru Cape, and in every case they are associated with the presence of fragmental volcanic matter.

The general idea of a single stratigraphical series being present is, we believe, very strongly supported by the fact that there is no place in New

* Trans. N.Z. Inst., vol. 37, p. 512, 1905. † *Loc. cit.*, p. 540. ‡ *Loc. cit.*, p. 531. § *Loc. cit.*, p. 494. ‖ *Loc. cit.*, p. 496.

Zealand where the members of one series rest on another with a development in any way approaching their normal character. This statement is true even if the unconformities described by different authors be accepted.

It is asserted by several geologists that one series has its typical development in the Oamaru area, and that another series is typically developed at the Waipara. There is no locality yet described where a series resembling that at Oamaru even in a general way can be found resting upon the lower or Cretaceous portion of the series at Waipara or Amuri. The same is true in a lesser degree of the other systems described.

When the numerous excellent sections in different parts of the country are considered, this remarkable fact appears to the authors to strongly support the view that is here adopted—namely, that there is a single series, of which the upper members overlap the lower, and hence in many places the series is restricted and the upper horizons only are represented.

It is noticeable that in all the bulletins issued by the reorganized Geological Survey under Dr. Bell it has not been found practicable to divide the younger rock-series into two or more systems.

VI. Correlation with European Horizons.

Any correlation of this nature must be purely tentative, except in regard to the lowest rocks at Amuri. The different correlations that have hitherto been made have been based on the percentage of Recent *Mollusca* among the fossil forms in different members of the series. This is wholly unsatisfactory, because (1) we do not even know with any exactness the present molluscan fauna, though this difficulty will disappear when Mr. Suter's "Manual of New Zealand Mollusca" appears; and (2) many members of the series, especially the greensands and limestones, were deposited in deep water, and our knowledge of the Recent fauna off the coast of New Zealand is, at most, fragmentary. The only comparisons that can be of any value are those between the littoral fauna of different strata.

It is not certain that we have at present a description of the fauna of the basement beds throughout the overlapping series, and it is therefore impossible to trace the changes that took place as time went on.

Some time must elapse before this can be remedied, for in the great majority of localities these beds do not contain fossils. Where fossils have been found they are of a very different nature in the various places. Thus, at Amuri Bluff and Waipara the lowest beds appear to contain no Recent species. The same is true of the Malvern Hills and Brighton, though here there are very few fossil species. At Black Point, in the Waitaki Valley, however, the number of Recent species is considerable. As previously stated, we believe that the series was deposited during a great lapse of time. The lowest beds are, at the latest, Eocene, and perhaps Upper Cretaceous; the highest of the conformable series are Upper Miocene or Pliocene.

If, as is here suggested, the limestone is of the same age throughout the country, it should be possible to come to a definite conclusion as to what that age is. The fauna that it contains are mainly echinoderms, *Polyzoa*, corals, *Foraminifera*, and sponge-spicules. Collections of each of these groups have been examined by specialists, and the following statements have been made by them:—

Tate said of the echinoderms, "There is no doubt that the Oamaru formation is correlative with the Lower Murravian of Australia." This,

he says, is comparable with the European Eocene, with a slightly more Cretaceous complexion.*

Tenison-Woods says of the corals, "I have no doubt that from the fossil corals the formation at Oamaru and that at Mount Gambier (of Australia) were contemporaneous. The stage accepted by him for the latter is a stage later than the Upper Eocene.† The same author examined the *Bryozoa* and compared them closely with the Mount Gambier formation of Australia.

Stache examined the *Foraminifera* obtained by the "Novara" expedition from Raglan and Whaingaroa. He classes them as the same age as those of the Vienna basin or of the Upper Oligocene of north Germany.‡

Hinde and Holmes classified sponge-spicules from Oamaru. They class the deposit as belonging to the Upper Eocene or Oligocene.§

In addition to these, the sharks' teeth of the greensand have been examined by Davis, who, however, makes no suggestion as to the age of the beds in which they occur.

It is evident that there is a general consensus in favour of the limestone from which all these groups of fossils have been obtained being classed with the early Tertiary, between the late Eocene and the late Oligocene. At present we do not intend any further correlation than this, and we believe that the late Cretaceous or early Eocene may be taken as the age of the oldest bed, the Oligocene as the age of the limestone, and the late Miocene or Pliocene as that of the youngest bed in the conformable series at Waipara. A skeleton classification is thus formed which can satisfactorily be filled up by the other members of the series.

It is the intention of the authors to state fully the palaeontological side of the question in future papers.

VII. SUMMARY AND CONCLUSIONS.

1. In all the sections of this series of younger rocks that we have had opportunities of examining in different parts of the country we have been unable to find any evidence of a stratigraphical unconformity in a single instance, though our observations have extended over those sections that have been regarded as crucial by different observers.

2. Though every geologist who has written about these sections previously has at one time or other insisted upon the existence of stratigraphical breaks, each observer has placed these in a different position in the series from the others.

3. The palaeontological evidence shows that the fauna which existed when the upper beds were deposited was very different from that which existed when the lower beds were deposited. It is also suggested that this rapidity of faunal change is more apparent than real, and that the strata of this series were deposited at a very slow rate.

4. Correlation has been confused because the overlapping nature of the upper members of the series has not been fully recognized. There is reason for supposing that it is correct to correlate all the conspicuous limestones of this younger series as contemporaneous.

5. So far as correlation with the European geological system is concerned, the limestone appears to be of early Oligocene age. The lowest beds of the series are perhaps Cretaceous, and the upper perhaps of Pliocene age.

* N.Z.G.S., 1892–93, p. 121.
† "Palaeontology of New Zealand," pt. 4, 1880, p. 4.
‡ "Reise der 'Novara': Palaeontology," p. 299.
§ Journ. Linn. Soc., Zool., vol. 24, 1892, p. 178.

Art. XXXIX.—*The Post-glacial Climate of Canterbury.*

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[*Read before the Philosophical Institute of Canterbury, 5th October, 1910.*]

The question of post-glacial changes in climate has attracted so much attention in Europe, and especially in Scandinavia, that it may not be out of place to consider certain indications which point to similar changes occurring in this part of New Zealand. It must be admitted at the outset that the evidence at present available is not strong, and that it is suggestive rather than conclusive; but the author hopes that this paper may serve to attract attention to the importance of the question, and to the desirability of doing our utmost here to make more complete observations in order to see if the same sequence of events followed the recession of our glaciers here as occurred in the British Isles and on the mainland of Europe. In the absence of undoubted evidence, the conclusions herein advanced are tentative in nature, and may have to be modified subsequently, but in disposing of them—if, indeed, that does happen—our knowledge of an important question will certainly be increased. When it is considered that in spite of the large numbers of skilled workers who are studying the question in Europe the differences on major points are very marked, and the conclusions arrived at on smaller ones are often diametrically opposed, the great difficulty of coming to any satisfactory conclusion on the matter in this country in the present state of our knowledge will be readily recognized. The generally accepted opinion as to late Quaternary climates in Europe is that after the recession of the ice, or partly contemporaneously with it, northern Europe enjoyed a climate much milder than at present, and that climate increased subsequently in severity. A school of physiographers, following the lead of James Geikie in Scotland and A. Blytt in Sweden, have urged the occurrence of a succession of maxima and minima of cold, an idea which has been supported by the work of Lewis in Scotland, and specially by that of the Geer-Senander school in Scandinavia, but their conclusions have received strong opposition from Gunnar Andersen and his followers. Seeing this great diversity of opinion among the leaders of thought on the matter, I may perhaps be excused if my own conclusions meet with criticism when the evidence is so much more scanty. I hope, however, that some of the peat-bogs of Southland, Central Otago, and Canterbury may be examined according to the Swedish methods, and an attempt be made to correlate, if possible, the events which followed the recession of the glaciers in this country with those that occurred in Europe. If this can be done our knowledge of the sequence of the general climate of the globe may be much increased.

The question of change of climate in Canterbury was first brought strongly under my notice on the occasion of a recent visit with Dr. L. Cockayne to the head-waters of the Rakaia River, and I am indebted to him throughout this paper for advice and kindly criticism which have been invaluable to me. I owe to him and to others who have helped me with information my sincere thanks for their assistance.

The idea that the climate of New Zealand has undergone marked changes since the retreat of the glaciers is by no means a new one. Captain Hutton

came to this conclusion as a result of his observations on the extinction of the moa (Trans. N.Z. Inst., vol. 24, 1892). He says, on page 154, "It is also evident that the dead moas could not have been washed into swamps under the present climatic conditions, and the solution of the problem is to be found in the fact that in Pleistocene times, when these deposits of bones were formed, the climate was very different from what it is now. . . . As the Pleistocene period passed away the climate no doubt got more equable, and the surviving moas once more increased and multiplied." His conclusion is based very largely on observations made in Central Otago, and on a study of the conditions under which the bones were found in the swamp at Glenmark, in North Canterbury. A peculiarity in the distribution at the present time of birds allied to the moa may be noted here. Related genera, such as the ostrich, rhea, and emu, now inhabit countries with a dry climate, and it may perhaps be the case that the moas established themselves in the South Island of New Zealand when the conditions were steppe-like in character and the moist climate was responsible for the diminution either on account of their unsuitability for such an environment or because it affected in some way their food-supply.

The moist climate suggested by Captain Hutton was certainly post-glacial, though it must be remembered when referring to his writings on the subject that he regarded the older Pliocene as the period of the maximum glacier-extension.

The latest pronouncement on the subject appears to be that of Professor von Lendenfeld, given in the volume published by the International Congress of Geology, 1910. In his article entitled "Das Quartäre Klima von Australien und Neu Seeland" he says, "Die natur der Gletscherzungen (Reisenmoränen, Seitentaler zwischen Gletscher und Talwand) macht durchaus nicht den Eindruck als ob dieser Rückgang der vergletscherung schon zum Stillstand gekommen wäre; sie deuten vielmehr darauf hin. dass er gegenwärtig noch fortschrietet, so das ich meinen mochte, dass in der Sudinsel von Neu Seeland, ebenso wie in Sudaustralien, das Klima gegenwärtig wärmer und trockener wird." The evidence on which this conclusion is based seems somewhat uncertain, but it is in all probability a general statement which would be quite true under any circumstances.

The purely geological evidence of the change in climate since glacial times rests firstly on observations of the behaviour of glaciers, as indicated by Von Lendenfeld; but this evidence is quite inconclusive, as they have been observed for a period too short to furnish data on which to base any well-founded conclusion. There is evidence of a fairly rapid retreat of the glaciers on the eastern side of the Alps; but the cause of this is unknown, although it is probably dependent on climatic changes. On the West Coast the Franz Josef Glacier is now rapidly advancing,* while the Fox Glacier, a near neighbour with very similar surroundings, was, when visited by the author three years ago, showing unmistakable signs of retreat. The Mueller Glacier, too, on the eastern side of the range, is showing signs of advance (*vide* Lands Report, 1906). It is possible that these advances depend on climatic conditions of a previous time which make themselves evident at the terminal face of glaciers of different lengths and velocities at different

* A recent map of this glacier, made under the direction of Dr. J. Mackintosh Bell, shows that the advance occurs principally on the northern side of the glacier, while the southern side is either stationary or actually retreating.

periods. Only after long-continued observations will it be possible to isolate the various anomalies and refer each to its exact cause. This line of inquiry, therefore, gives at present little satisfactory result except in so far that a recent rapid retreat must be granted, but whether this retreat is periodic or not is quite uncertain.

There is geological evidence of a dry climate obtaining over the region in question either contemporaneously with the extension of the glaciers, or somewhat subsequent to it, in the fact that the loess which so completely mantles the country was a rock-flour carried by wind from the river-beds of glacial rivers. This is the general opinion of its origin, although Captain Hutton maintained that this same deposit was a marine silt. It probably indicates that the conditions over the east coast of this Island resembled somewhat those which occur in Thibet at the present time, only they are not so pronounced. A reference to this probable steppe climate will be made later when mentioning the xerophylly of certain New Zealand plants.

Further conclusions may be based on the examination of the terraces which characterize the valleys of nearly all the rivers of New Zealand. Hutton attributed these almost entirely to a recent rise of the land giving all the rivers increased power of corrasion. In a paper on "The Terrace-development in the Valleys of the Canterbury Rivers" (Trans. N.Z. Inst., vol. 40, 1907) I have given my reason for thinking that, as far as Canterbury is concerned, the major movements have been downwards since glacier times, and that unless the land has been differentially elevated quite recently along an axis almost coincident with the main range, or closely parallel with it, mere elevation cannot account for the characteristic features of the terraces. In that paper I urged the importance of the falling-off of the supply of waste owing to the lowering of the land, thus giving the rivers increased power of corrasion, as the principal cause for their occurrence. I have since seen reason, based on wider observation, to modify this opinion. While admitting the necessity for attaching greater importance to the supply of waste, and recognizing its great influence in the case of the large rivers of Canterbury, there are numerous terraces which cannot be attributed to that cause. Observations made recently on the small fans of detritus in the dumping-grounds of mining claims confirm my opinion that they are built up chiefly when the supply of water and its accompanying load of waste is plentiful, but that, when the supply of water is diminished, terracing of the fan immediately results. The profile of these terraces reproduces exactly those which occur on our large shingle-fans, and also those formed by the rivers which cross the Canterbury Plains. The inference seems, therefore, that the material of our river-terraces was brought down in a pluvial epoch, and terracing commenced actively when the supply of water began to fall off. This course does not affect the principle that supply of waste is also an important factor affecting the formation of terraces. The condition of many of our Canterbury streams at the present time, when deposition is overtaking transportation in the lower portions of their courses, is evidence that a maximum of erosion is past and another cycle of deposition has commenced. This may be due to the lowering of the land, but it may be due to a change in the supply of rain or to alteration in the climatic conditions.

These are the chief lines of evidence of purely geological character which are connected directly with the question, but there are others of biological character which must be considered. The first of these concerns the

character of the land *Mollusca*, and the others are more or less botanical, and have to do with the peat-bogs and the forests which formerly covered wide tracts on the now treeless or almost treeless regions of Central Otago and Canterbury.

LAND MOLLUSCA.

I am indebted to Mr. H. Suter for the following remarks on the land *Mollusca* of the area. He says that they are certainly of a moist-climate type, that the indigenous fauna is almost entirely confined to the bush, and when this is destroyed or where there is no shelter from rotten logs in moist situations, it disappears entirely. It must, therefore, have established itself in this province when the climate was wetter. This argument standing by itself is not convincing, as the establishment of this snail fauna might date from a time anterior to the glaciation; but taken with other evidence it seems to strengthen the general conclusion that the climate was once moister than it is now.

EVIDENCE FROM PEAT-BOGS.

The evidence afforded by the peat-bogs of this country will, when they have been properly studied, give data from which well-founded conclusions can be drawn. At present their features are comparatively unknown, and the statement still finds currency that they do not contain *Sphagnum* (J. W. Harshberger: "Bogs, their Nature and Origin"—"The Plant World," vol. 12, p. 36, 1909), although it really finds an important place among peat-forming plants where the conditions do not allow of good drainage. In some cases where the drainage is bad, and again in other cases where it is good, other plants contribute largely to the formation of the peat. In these cases their ecological conditions are not thoroughly understood at present, but they no doubt depend in some way on climate. Bogs composed of *Sphagnum*, and also those formed otherwise, occur extensively in both Canterbury and Otago, especially the latter. In the early days of the settlement, peat was regularly cut from the bogs of the central district of Otago and used as firing where wood was scarce. Extensive bogs were found then on the tops of the flat-topped mountains, such as the Rock and Pillar and Rough Ridge; and Dr. Hilgendorf tells me that in the Waipori district twenty-five years ago these bogs were full of totara logs, and other logs lay exposed on the surface of the ground round the heads of gullies in such a way that their distribution could only be explained by supposing them to have been once bog-timber, which had been left stranded as the bogs shrank. These bogs mentioned by Dr. Hilgendorf were in all probability not composed of *Sphagnum*, but there are others which do contain wood and undoubtedly owe their origin to that moss. Dr. Hilgendorf's statement that the bogs are shrinking in size is a very important one, and if it could be absolutely substantiated it would prove that the climate has undoubtedly changed; but the effect of running stock over bog land tends to consolidate it, and his statement, unless supported by other evidence, would have to be taken with great care, seeing that sheep and cattle have been pastured on these lands. I certainly think that such evidence exists. It must be observed in this connection that the existence of *Sphagnum* bogs in the dry region of Central Otago, with an average yearly rainfall of about 14 in., and with periods when it has fallen as low as 7 in. per annum, is very striking, since it has been proved that the growth of *Sphagnum* depends chiefly on the water that it receives from the

atmosphere, and not on ground-water. With reference to this, E. Warming says ("Ecology of Plants, p. 201: Oxford, 1909), "It is erroneous to suppose that *Sphagnum* sucks up water from the soil; it raises water for an inconsiderable distance. The movement of water in a *Sphagnum* moor is essentially a descending one."

The conditions of Central Otago at the present are not favourable to the growth of peat, and those bogs which I have examined do not show any distinct signs of renewal after being dug out for fuel, as they should do if the conditions were favourable for its growth. This seems to bear out the statement that the climate is becoming drier. More careful work will, however, have to be done before this can be definitely established.

Some of the bogs contain abundant remains of the roots and stems of *Dacrydium Bidwillii* (?). Although no positive evidence could be obtained that this shrub or low tree grew on the bogs, it is nevertheless extremely probable that this was the case, since in many parts of the alpine region of the Southern Alps it is a typical bog-plant, although it will grow also in somewhat dry places. The roots are common in the peat which covers the *roches moutonnées* of the Upper Waimakariri Valley and other places along the eastern flanks of the range, and it occurs in well-defined layers in the peat-bogs on the line of the Midland Railway near Sloven's Creek, between Broken River and the Cass. These latter may have been swept in by floods when the climate was more rainy than at present, or they may have grown in position on the bog. The presence of well-defined layers of trees and stumps probably points to recurrent periods when the climatic conditions favoured its growth either on the bog or on neighbouring land-surfaces. At the present time in some of the bogs a keen struggle for existence is going on between the *Sphagnum* and the pine. It is likely that in drier conditions the latter would have the advantage, and temporarily extinguish the bog, as has been assumed to be the case with the pines in the old peat-bogs of Scandinavia and Shetland; but this conclusion is open to serious criticism. Whatever the causes controlling the relative growth of these two elements, the presence of the layers of wood and peat points to recurrent conditions, or, rather, to probable alternations of moister and drier climate, as a very slight change in one direction or the other may be a determining factor in the struggle for existence between the *Dacrydium* and the *Sphagnum* and other peat-forming plants.

The Presence of Former Forests.

Before the arrival of Europeans, and partially contemporaneous with the early settlement, extensive forests containing trees which flourish in moist situations extended over wide areas to the east of the Southern Alps and over Central Otago which are now almost if not entirely treeless. The existence of this forest is undoubted, and its disappearance is usually put down to fires before the arrival of Europeans or in the very early days of the settlement, an explanation which is extremely questionable and not supported by undoubted evidence. The Rev. J. W. Stack, an authority on the Maori history of this part of New Zealand, includes the tradition of the destruction of these forests by fire among those on which little reliance can be placed, though he remarks that there is no impossibility that they were so destroyed.

The evidence for the existence of this forest is largely based on the observations of the early pioneers and other observers who followed

immediately on them. These men noticed large logs of totara (*Podocarpus totara*) among the grass and in slips and swamps over very wide areas in Canterbury. The logs were frequently charred, and it was immediately assumed that the former forests were entirely destroyed by fire. The whole question is greatly complicated by the destruction of the evidence by the fires lit by settlers in the early days to clear the country from the rank growth of tussock-grass, so that now there is little proof of absolute value still remaining except in the records and recollection of these settlers. In those cases where I have had to rely on the evidence of such observers I have given their names, and I take the opportunity to thank them for much information of value on the point.

Large totara logs lay plentifully on the foothills along the eastern base of the mountain region of Canterbury. They were found in quantity on the hills around Cheviot at a height of about 1,700 ft. (C. J. Westland); on all the country between the Hurunui and the Waipara Rivers, and on the Moeraki Downs, above a height of 800 ft. (P. J. Overton); on Teviotdale, near the coast-line; at Amberley (James Hay); on the Malvern Hills, as mentioned by Lady Barker in "Station Life in New Zealand." On the arrival of Europeans the present Oxford Forest extended down the Eyre River till it nearly junctioned with the bush then existing near Rangiora; this is proved by the logs formerly lying on that part of the plains. Extensive tracts were covered with bush on the downs behind Timaru (J. Hardcastle), for large logs of totara are even at the present time found in the small creeks of that now treeless country.

The same is true of other parts of the province near the mountain axis of the Island, as, for example, the Mackenzie country, and the valley of the Cameron River in the basin of the Upper Rakaia. On Banks Peninsula, too, there is evidence for a former greater extent of forest. The top and exposed northern slope of Mount Herbert, on the southern side of Lyttelton Harbour, were bare of trees on the arrival of the earliest settlers, although the gullies held patches of bush; and the country was probably in the same condition when Cook saw it from the ocean half a century before. However, numerous logs of totara are even now found on the very summit of the mountain.

According to my own observations on Banks Peninsula, the points of many of the spurs dividing the bays were absolutely treeless and covered with tussock-grass for a considerable distance from their terminations. This was especially the case on those spurs running north-east near Little Akaloa and Pigeon Bay. It might be urged that salt-laden winds from the sea had killed off the trees in these exposed positions were it not that certain spurs equally exposed were wooded right up to the very edge of the cliffs. According to observers of absolute reliability, in breaking up the open land on such a spur for sowing down in English grasses, buried totara logs of fair size were frequently found far from the edge of virgin bush.

I cannot get any satisfactory evidence that logs lay on the surface of the Canterbury Plains south of the Waimakariri, but large trees of totara have been found buried from 6 ft. to 10 ft. deep in the shingle-beds near Christchurch—as, for instance, at the city waterworks, near the foot of the Port Hills. These were undoubtedly of drift-wood, but the trees were in some cases over 2 ft. in diameter, were perfectly sound, and were used for posts in the fences round the buildings. The trees must have been brought down from some forests that grew either on the plains or further away in the mountains, probably by the Waimakariri River in one of its excursions

away from its present bed across the plains, as only a very large river would be competent to move such enormous logs. The former extension of the bush on the plains is proved by the occurrence of vast quantities of fallen timber and numerous stumps in position throughout the belt of country stretching from just north of Amberley, through Woodend at the north of the present Waimakariri, and through Marshland on to Christchurch. The present writer has examined such a forest with trees *in situ* when the excavations were being made for extensions at the Christchurch Hospital. This forest belt extended south through Tai Tapu, round Lake Ellesmere, towards the mouth of the Rakaia, and again on towards Timaru, since extensive deposits of swamp-timber are found near Longbeach, between Ashburton and the sea, and again from the mouth of the Orari River to the termination of the downs just north of Timaru.

On several parts of the coast-line the roots of trees are found in position either submerged below the level of lakes or within the limits of the tide. Such occur in Lake Ellesmere (J. Rennie), at the mouth of the Opihi (J. Hardcastle), near Washdyke, and again near Pareora (W. Wilson). These show distinctly that the coast-line has been sinking recently, a movement in all probability only a phase of the great sinking movement of the land which, with minor temporary rises, set in during Quaternary times.

This coastal forest was largely of swamp origin, and it was composed chiefly of white-pine, or kahikatea (*Podocarpus dacrydioides*), and manuka (*Leptospermum scoparium*), the former a tree which makes a pure association principally on swamps, and the latter a very xerophytic type, but found freely on all classes of soils and in many situations. Remains of black-pine (*Podocarpus spicatus*) and ribbonwood (probably *Plagianthus betulinus*) are also found. On the arrival of Europeans relics of this forest existed in a few localities on the plains—for example, at Riccarton, Papanui, Woodend, Rangiora, and at Temuka. These were mostly of white-pine, black-pine, pokaka (*Elaeocarpus Hookerianus*), and totara as the timber-trees, in that order of importance, but with little of the last-named. The presence of this swamp-forest was largely determined by the presence of moisture in the form of ground-water, but its disappearance from certain areas may be due to the fact that they had become so swampy that even trees like white-pine could not maintain themselves in the presence of so much water, this tree being really an oxylophyte—that is a xerophytic form which has adapted itself to moist conditions. It is possible, therefore, that the disappearance of this forest may be partly due to altered climate, although the waterlogging of the soil may be also put down to the sinking of the land which has taken place in fairly recent times.

Apart from this coastal forest there were at the beginning of settlement considerable areas of standing bush, containing totara, black-pine, and white-pine, at Mount Peel, Geraldine, Waimate, and specially on Banks Peninsula, as well as in a few other localities in hilly places favoured by a good rainfall and a rich soil. At Mount Peel a considerable area still remains. These were in all probability remnants of a regional forest containing totara which covered extensive areas on the eastern slopes of the main range of the South Island. Excepting that which remains at Mount Peel, its most extensive remnant occurs now in the valley of the Upper Rakaia. Here for miles on the northern bank of the river the slopes of the mountains are covered with a thick forest composed largely of this tree. It occurs also in patches on the southern bank. In this locality the wet westerly winds reach well across the main divide, and the mountains to the

south of the river shelter the upper part of the valley from the cold southerlies, so that the climatic conditions are eminently favourable for the growth of this tree. Its former extension in the vicinity is proved by the logs which occur now on the south-eastern flanks of Mount Arrowsmith, in the valley of the Cameron River (L. Wood and the author), a district which is now marked by the presence of a xerophytic vegetation.

The extension of this forest into Central Otago was noted by the earliest explorers and settlers, for a noteworthy feature of the land-surface in its original condition was the occurrence of enormous numbers of logs of totara lying on the hillsides and flat-topped mountains, as well as buried in the slips and bogs of that now treeless and steppe-like region.

In his sketch of the "Botany of Otago" (Trans. N.Z. Institute, vol. 1, 1869) Buchanan says, "The general facies of the vegetation of the province on its eastern watershed is grassy, the greater part being open grass land with comparatively small areas of bush along the coast-line and in the gullies of the mountain-ranges, whereas on the western watershed the whole country from the sea to the altitude of 3,000 ft. on the mountains is covered with bush. It is evident that at no distant time the greater part of the province was covered with forest. On many of the grassy ridges may still be seen the remains of large trees, and over large areas the surface is dotted with little hillocks and corresponding hollows produced from the upturned roots of trees which have been blown over, generally in the line of the prevailing winds, after their destruction by fire, and no doubt there have been many denudations and reproductions of bush. At the beginning of the settlement large tracts of the province were being reclothed with bush, but as the country was opened for cattle and sheep runs this new growth was again burnt off, and a luxuriant growth of native grasses appeared without seeds being sown." This account was written in the year 1865, and is specially important as showing that a competent observer at that early date was of the opinion that a succession of forests had covered the treeless hills of Otago.

The existence of vast numbers of totara logs in Central Otago is testified to by many other observers, all of whom have acknowledged that the prostrate trees indicate the presence of a forest of wide extent. The latest reference to this appears to be that by Professor Park, in Bulletin No. 5 (n.s.), New Zealand Geological Survey. The author there says, "Forest vegetation is entirely absent, but there is evidence that it was not always so. Above the 2,000 ft. contour-line of Mount Malcolm and Mount Hocken there are still many logs of totara (*Podocarpus totara*), charred and well preserved, lying on the surface of the ground. The older settlers state that totara logs were at one time common on the Dunstan, Pisa, Carrick, and Remarkable Mountains, and proved of great value to the early pioneers for fuel and fencing purposes. The totara forests apparently flourished above the flood-level of the Pleistocene rivers that filled the old lake-basins. They were probably destroyed by fire."

The occurrence of the totara in the peat-bogs of Otago is referred to earlier in this paper.

Although the evidence for the wide extent of this forest is conclusive, it cannot be maintained that it covered the face of the country as completely as do the forests on the western slopes of the Alps. All the same, it may have done so. The usual sequence of events in the changes which forest experiences in this region is that when destroyed by fire, wind, or any natural cause it turns into tussock steppe. The transition is at times very rapid,

so that it is very probable that a large part of the tussock country of this Island was once bush-covered. However, some areas must always have been in existence on which there was no bush, where the tussock was established, and from which it could spread to neighbouring tracts when the ecological conditions were favourable for it doing so.

Continual reference has been made previously to the occurrence of totara logs, and the inference will probably be made that the forests were largely, if not wholly, of totara. In all probability such was not the case. At the present time few areas are covered completely by this tree. It occurs widely distributed through many kinds of bush, but it also occurs at times in groves several acres in extent. It was in all probability only a constituent of the former forest, and its predominance among the timber lying on the ground is due to its uncommon power of resisting decay. It is one of the most long-lived of timbers when in damp situations. Other specially resistant timbers, such as broadleaf (*Griselinia littoralis*), are also found, so that in all probability the woods which grew with it have long since rotted away. It must be noted in this connection that I am not referring here to bog-grown timber, such as the manuka, which is so common in so many swamps.

Since totara was undoubtedly a prominent constituent of this forest, the conditions under which it grows have a very important bearing on the question of the climate which obtained in the area when the forest established itself. Although it is not a rain-forest tree in the same sense as the rimu (*Dacrydium cupressoides*). and although it is perhaps the most xerophytic of all the New Zealand conifers (*vide* paper by Miss Griffin, "The Development of some New Zealand Conifer Leaves," Trans. N.Z. Inst., vol. 40, 1908), it is nevertheless a tree which flourishes under conditions of good drainage with a damp atmosphere, and specially on deep rich soils—it is, in fact, a prominent member of the New Zealand rain forest. It will grow on light pumice and sandy soils if they have plenty of rain, as well as on heavy clays, and even at times on swamps; but the existent patches of bush containing this tree in quantity, and also those which furnished a large part of the totara for timber purposes in former times, were in localities with a good, if not a heavy, rainfall. The "totara areas" of the North Island, according to the report made in 1875 by Major Forrestier Walker, were those tracts along the central mountain axis of the Island and near Lake Taupo which had a rainfall of 40 in. a year and upward. To take, for example, the totara forest on the northern slopes of Tongariro and the Waimarino Forest, which contains in parts a large quantity of that timber: they are both situated in a part of the central plateau which receives a heavy rainfall from the west, while the dry eastern slopes of the Ruapehu-Tongariro ridge are either treeless or dotted with patches of *Nothofagus cliffortioides*, and the charred fragments of wood in the pumice-drifts which cover that region seem to be from that tree and not from totara.

The distribution of totara is the South Island, occurring as it does in such localities as Banks Peninsula, Peel Forest, at Glenomaru in the Catlin's district, as well as near the east coast about Dunedin, shows that this tree delights in a well-drained soil, with plentiful supply of rain. It also occurs on the excessively moist hills and swamps of Westland, but in the latter it does not thrive. The forest now existing at the head of the Rakaia is merely an extension of the subalpine totara forest of Westland which has

followed the rain across the main divide, and the fact that this tree out of all the rain-forest trees of Westland has done so is really very striking.

Judging from the rainfall records kept at the Bealey, where the usual amount for the year averages about 100 in., and has reached as much as 136 in., the rainfall of the Upper Rakaia Valley, which is exactly similarly placed as regards the main range and the direction of the rain-bearing winds, must certainly approach, if it does not exceed, 100 in. per annum. The climate is decidedly moist and the drainage is good, and under these favourable conditions the totara occurs so plentifully in parts of the district that it virtually excludes other forest-trees.

These facts seem at variance with the xerophytic-adaptation structure exhibited in the leaves of the tree; but this is one of the many cases which have been pointed out by Dr. Cockayne where there is a marked discrepancy between the actual structure and the structure one would expect the plants to show judging from their habitat alone. In his "Notes on the Subalpine Scrub of Mount Fyffe" (Trans. N.Z. Inst., vol. 38, p. 373, 1906) he says, "The amount of xerophylly in many New Zealand plants is by no means a measure of their adaptation to present environment, but is more likely a survival from a former geological period when xerophytic conditions were more widespread." This opinion is a very important one from a geological as well as from a botanical point of view, and it agrees with that of Dr. L. Diels, quoted in Dr. Cockayne's "Plant Geography of the Waimakariri" (Trans. N.Z. Inst., vol. 32, p. 122, 1900). Dr. Cockayne's statement about the xerophylly of New Zealand plants probably applies to the totara, though it is no doubt possible that the advantage of possessing a moderately xerophytic structure would aid it in its struggle with other plants under increasingly dry conditions, and therefore may explain its importance as a forest-tree in the forests which grew formerly over the somewhat arid regions on the east coast of this Island.

The date of this former forest-extension is fixed as being certainly post-glacial, since the remains are commonly found in localities which must have been covered with ice, according to the most conservative opinions as to the extent of our former glaciers; and it must certainly have been posterior to the great glaciation postulated by Professor Park, as the region where these logs now occur in Central Otago was, according to him, covered with a great ice-sheet. It is possible, however, that, as the glaciers retreated from their furthest extension, the forest established itself *pari passu* on the areas left free by the ice, just as they are now doing in the case of the Franz Josef Glacier. The space of time taken for the gradual extension of such a forest over regions swept bare of soil by the glaciers must have been enormous, and if there has been a succession of forests, as suggested by some observers, then the time must have been very great indeed.

The question of the extent of these forests and the conditions under which the totara grows have been gone into somewhat at length because, in my opinion, it is possible to make the deduction that when the forests established themselves the conditions must have been much different from those obtaining now. It has been just stated that the forests have extended over areas which in Pleistocene times were covered with ice, and were probably dry and steppe-like. Before they could do this the climate must have changed, as the New Zealand rain forest requires a moist climate for its growth. This conclusion seems to agree with those deduced from other observations. I must explain, however, that this conclusion is merely

tentative, and is based on observations of the ecological habits of the totara which are decidedly incomplete.

Reasons for the Disappearance of the Forests.

Although the main point to consider in this paper is the question of the establishment of the forests on an ice-swept country, yet their disappearance has also an important bearing on the question. In several parts of the country it has been noticed that the bush is shrinking even when protected from the interference of man and animals. Far larger areas in the North Island were once covered with kauri forest than those which existed in the memory of man, as is proved by the extensive deposits of subfossil kauri-gum far away from growing timber. This is quite apart from the gradual restriction of the kauri forest which has gone on in Tertiary times from its former wide range, proved by the occurrence of fossil kauri-leaves in various Tertiary deposits in Otago. The destruction of the forests containing totara, which once existed in Canterbury and Otago, has usually been put down to the fires lit either accidentally or intentionally by the Maoris, a conclusion largely based on the fact that many charred logs were found by the earliest settlers. There is a Maori tradition, mentioned previously, of the destruction of these forests by extensive fires at one period of Maori history; but the evidence from Maori tradition is almost valueless, and there are indications from Canterbury which certainly point in a contrary direction. Banks Peninsula was thickly peopled by Natives at the time of the arrival of the first settlers and it showed no signs of the ravages by fire (S. C. Farr). If fires had been lighted by the Maoris this is just the place where they should have occurred, yet the hillsides, with the exception of the highest points and some of the headlands, were completely clothed with bush right up to the very settlements of the Natives. The bareness of the headlands seems to have been due to other causes, since from their relative inaccessibility they were not likely to have been swept by fire. These open spaces were probably due to that natural succession of events which turns forest into grass land, but the factor controlling this change does not seem to be well understood, and it may be a function of the change in climate. At the same time, it must be admitted that continuous and repeated fires in dry seasons, fed with accumulations of dry tussock-grass, would restrict materially the areas covered with bush, and without doubt these fires occurred.

It seems impossible, however, that fire could have destroyed a forest of wide extent and left no patches in sheltered gullies and other places which would have formed centres for its renewal *had climatic and other conditions been favourable.* If the climate is favourable for the renewal of the rain forest it is difficult to destroy it by burning, even when this is carried on for the express purpose of clearing the land for pastoral purposes. In the case under consideration, the charring of the logs mentioned previously has been caused largely by tussock-fires since the arrival of the white man, although the Maoris certainly carried on a sporadic burning in pre-European times. It is a remarkable fact, however, that the existing patches of bush occur in just those situations in which they might be expected to occur from ecological considerations had a slight desiccation of the climate come about. The bush has disappeared from situations where from exposure to wind, lack of moisture, &c., they would naturally feel first the effects of slightly drier atmosphere. The change required to produce this disappearance is no doubt very slight, as little is required to upset the delicate

balance which exists between the struggling elements of different plant associations. It seems, therefore, that a slight desiccation of the climate can be inferred from the restriction of this forest. The disappearance had in all probability begun before the arrival of the Maori, following on a period of drier climate after a moist period which favoured its growth. The forests would then be specially subject to the action of fire, except in those places favoured by moist conditions. Fire certainly aided in their destruction, but it is improbable that it was wholly responsible for it.

The present conditions are decidedly dry over a large tract of country to the east of the main range; however, this is due not altogether to lack of rain, but to the influence of parching winds. Under the combined influence of these two agents the vegetation is now markedly xerophytic, but when the plants are grown in a moist and still atmosphere they readily revert to leafy forms, as has been proved by the experiments of Dr. Cockayne on the wild-irishman (*Discaria toumatou*) ("The New Phytologist," vol. 4, p. 79, 1905). Dr. Cockayne has suggested to me that this readiness to revert to the leafy form may be due to the fact that at some period anterior to the present somewhat dry one the prevailing climatic conditions were moist, and that owing to the environment the tendency to become more or less permanently xerophytic was checked, and the ability to respond quickly to a moist atmosphere has been kept latent up to the present time.

I am aware that this evidence is not convincing, and that it is merely sufficient to establish a *prima facie* case for consideration. If, however, the conclusion that a rainy climate succeeded the last glacier maximum over a wide area to the east and south-east of the Southern Alps be accepted, the reasons for such a change may be briefly considered.

This moist climate may be attributed to one of two main causes—(1) a marked lowering of the land in post-glacial times, with a general climate much the same as that which obtains now; or (2) a change in the climate affecting a wide area, or even the earth as a whole.

Cause of the Change.

A marked lowering of the land in this region of moisture-laden westerly winds would have the effect of making the climate uniformly humid over the whole of the country, instead of being, as now, subject to an abnormally heavy rainfall on the west of the range, while the east is comparatively dry. With lower mountains the total amount of rain intercepted would in all probability be much less than that which would be intercepted if the mountains were higher, but it would be more uniformly distributed. The humidity of the climate depends as much on the number of rainy days as on the number of inches that fall during the course of the year—for example, the climate of the Chatham Islands is markedly humid with a comparatively small annual rainfall. However, before lowering of the land could produce a humid climate in the Mackenzie country or in Central Otago the land would have to be lowered by hundreds, perhaps thousands, of feet below its present level, in order to allow the extension of the moisture-bearing clouds over the ranges near the coast, so that the interior of the country might receive a share of their moisture; and there is no evidence of such a lowering since glacial times. Even if the old beaches found in various parts of the south of this Island were post-glacial — which is open to doubt — the amount of sinking that they indicate is totally insufficient to have produced a moist climate over that part of the country which lies along the east of the range. It seems

reasonable, therefore, to attribute the humid climate either to causes which have affected the earth as a whole or to altered meteorological conditions promoted by some change in the distribution of land and water in the Southern Hemisphere.

Conclusion.

The general sequence of events since the glaciation of the South Island in Pleistocene and post-Pleistocene times appears to have been the following:—

(1.) Glacial conditions, with probable steppe climate existing contemporaneously on the land to the east of the terminations of the glaciers, a condition which probably continued for some time, as the glaciers were retreating.

(2.) Moist climate over the tract to the east of the main range, during which the forests were established or were widely spread and the rivers built up their fans.

(3.) Modified steppe conditions over the belt to the east of main range.

The conclusions are, in general, similar to those which have been agreed upon by European geologists as occurring in Europe, although an important school has demanded the existence of a succession of warmer and milder conditions. Of course, it is impossible at present to make any inference as to such a succession of milder and more severe climates in New Zealand, or even to infer that the changes in climate suggested by the various lines of evidence indicated above were contemporaneous. Some of the changes suggested may be due to causes which operated in Tertiary times. However, in view of the general interest in the matter, the author hopes, in spite of obvious deficiencies in the statement of the case, that this paper may serve to draw attention to a problem which has an important bearing on the climate of the world as a whole, and also on the evolution of the vegetation and the plant-associations which exist at present in this country.

Art. XL.—*A Preliminary Account of the Geological Features of the Christchurch Artesian Area.*

By R. Speight, M.A., M.Sc., F.G.S.

[*Read before the Philosophical Institute of Canterbury, 7th December, 1910.*]

Plates IX–XIV.

[Note.—This paper embodies the results available at present of an examination of the beds of the Christchurch artesian area. Although they are necessarily imperfect, it has been thought advisable by the author to submit them in this form, as they are complete in some respects; in others, they are quite imperfect, and observations extending over several years will have to be made before any finality in the conclusions can be reached.]

Introductory.

The part of Canterbury stretching along the coast-line from the mouth of the Waimakariri to the west of Banks Peninsula as far as the mouth of the Rakaia is perhaps the most extensive area in New Zealand where plentiful supplies of water can be obtained from artesian wells. The interest which

attaches to this tract of country is not one of economical character alone, since an accurate examination of it may throw some light on the structure of the Canterbury Plains, and indirectly on questions of more theoretical interest, such as the cause of the Pleistocene glaciation of this country, which has lately attracted so much attention. The amount of evidence to be considered is very great, as no part of the earth's crust in New Zealand has been more thoroughly explored than this area. The number of wells already sunk extends to thousands, and of late years all well-sinkers in the transaction of their calling, in order to be able to give accurate estimates of the cost of sinking in various localities, have kept detailed records of the wells they have sunk, and made careful note of the depth of water-bearing beds, the amount of water obtained at certain levels, the nature of the strata encountered, and the thickness of the beds.

The records of various well-sinkers have been placed at the disposal of the present author, and every assistance in the way of information has been given when it has been asked for. The writer wishes especially to thank Messrs. J. Osborne and J. W. Horne for assistance in this respect. It has thus been possible to examine the records of more than five hundred wells, so that an accurate conspectus can be obtained of the whole water-bearing area.

General Structure of the Canterbury Plains.

The detrital deposits of the Canterbury Plains have been laid down on a basement rock of uncertain character, but there is evidence which suggests that the same formations as occur in the western part of Canterbury are continued beneath the plains to the eastward, and extend under the sea towards the Chatham Islands. The greywackes and slates of the Southern Alps outcrop again near Gebbie's Pass, on Banks Peninsula; and the Chatham Islands are formed of schists analogous to those of Westland, overlaid by Tertiary limestone and volcanic rocks, the former of which can be correlated with limestone of Miocene or Oligocene date in the main islands of New Zealand.

The only evidence of the structure beneath the sea which stretches from the Chathams to Banks Peninsula is that afforded by the collections of the steam-trawler "Nora Niven" when carrying on an experimental cruise on behalf of the New Zealand Government. As recorded in a note to a previous paper by the present author, the trawl brought up from a number of stations parallel with the coast-line, and in depths of between 20 and 40 fathoms, pieces of brown coal sometimes as large as an ordinary travelling-trunk. It is hardly credible that these could have dropped from passing steamers, seeing that brown coal is rarely if ever carried by sea, and it is impossible that they could have been brought down by rivers from the coal-seams that occasionally outcrop on their banks, since such pieces would be rapidly reduced to powder and become indistinguishable among the other detrital material. It must be concluded, therefore, that the coal has been derived from an outcrop on the edge of a submarine escarpment which runs parallel to the coast and with its beds probably dipping west. These may continue westward, and, passing under the plains, junction with the coal-measures which fringe the eastern flank of the mountainous district of Canterbury. The beds would then take the form of a syncline, slightly tilted towards the east, with its eastern wing depressed beneath sea-level. Further, they may form part of a great ge-syncline or synclinorium

extending over the whole area from the Alps to the Chatham Islands, with schists outcropping on its eastern and western visible limits.

The uncertainty of the soundings between Banks Peninsula and the Chathams renders it impossible to speak definitely of the form of the sea-bottom in that region, but it appears from the few that have been obtained that the sea gradually deepens for about forty miles, to the 100-fathom line, and then suddenly drops to over 1,000 fathoms, a depth which is maintained to the vicinity of the Chathams. Whether this is part of a submarine plain or a portion of a fold valley which runs in a north-easterly and south-westerly direction parallel to the coast of the North Island is at present uncertain, and it is hoped that the efforts being made in Wellington to get a line of soundings run from Lyttelton to the Chathams may be successful, as it will throw considerable light on the evolution of the main crustal features in this region.

That a syncline exists involving the Cretaceous coal-measures, and probably the overlying limestones, seems to be very reasonable, but the cause of its form is uncertain. It may be due to deep-seated movements of the earth's crust, of which we can say little at present, or it may be due to loading caused by the immense quantities of detritus poured into the sea by the great Canterbury rivers. The presence of a line of earthquake origins parallel to the coast-line of the plains suggests crustal movements along a line in the neighbourhood of the probable submarine coal-outcrops.

Source and Character of the Material out of which the Plains are constructed.

The detrital matter out of which the plains are constructed consists chiefly of shingle with an admixture of sand and silt, the whole being formed from the weathering and disintegration of the greywackes out of which the great mass of the Canterbury mountains is formed. In the higher parts of the plains, near the base of the mountains, there is a considerable mixture of angular matter and large subangular blocks, but in the lower parts of the plains the gravel becomes much smaller. The fragments are usually from 2 in. to 4 in. in diameter, and rarely exceed 8 in.; they are well rounded, and seldom exhibit the flattened ovoid form produced by the incessant drag of the backwash on a beach subject to heavy seas. It cannot, however, be inferred with certainty, because the pebbles on the plains are usually of such equilateral dimensions that they must have been formed wholly by river-action, as the shape of a pebble on the beach is primarily determined by the shape of the block from which it has been derived. On examining a beach of limestone pebbles on the north side of Amuri Bluff, I was struck by the frequency of the cricket-ball size and shape, and this could only be due to the original fragments having been cuboid in form. The angular fragments produced by the disintegrating action of the frost and other agencies on the mountains of Canterbury are usually of equilateral dimensions. However, on examining the beach at Birdling's Flat, between Lake Ellesmere and the sea, it will be noticed that a very large proportion of the pebbles exhibit the true shingle form as distinct from gravel. If the plains had been formed by marine action they must have been subject on their eastern margin to attrition by the same heavy seas that sweep up the present Ninety-mile Beach, and therefore beach-shingle should form a large part of their material. As this is not the case, I think it may be inferred that

the plains have been built up on a land-surface by the aggrading action of the rivers issuing from a mountain tract, where they are plentifully supplied with sediment and flowing on a high gradient, and then depositing their load at the base of the mountains, where their transporting-power is less. Such plains occur under somewhat similar conditions at the base of the mountains in central Asia and central United States, where marine action cannot be called in to explain their approximately level character. The present contours of the plains, as shown by the detailed surveys of Haast and Doyne, emphasize their fluviatile origin, since they are just those which would have been exhibited had the plains been built up by the coalescence of the fans of low gradient formed by the large rivers as they issued from the mountains.

FORMATION OF THE EASTERN PART OF THE PLAINS.

There are certain factors which must be allowed for when considering the formation of the eastern portion of the plain. The rivers have been bringing down for a long period vast quantities of the detritus. On the Ninety-mile Beach this is exposed to a strong northerly drift up the coast, which sweeps it northward and piles it up against the southern coast of Banks Peninsula. When the supply of shingle fails, the sea encroaches on the land, as, for instance, near Oamaru, where works are necessary for the protection of the town, and the neighbouring coast northward to the Waitaki River is being rapidly attacked. This river brings down an enormous amount of material, and in consequence the coast immediately north of its mouth is advancing in spite of a probably downward movement of the land, evidenced by the valleys in the dolerite plateau near Timaru, which have the outlets depressed below sea-level, and also by the presence of submerged forests on the coast near the mouth of the Pareora River. The gradual pushing-forward of the shore is evident right up to Timaru. The railway-line is placed for the greater part of its length on the level beach which has accumulated at the base of the cliffs, now removed some distance from the sea. Some idea of the importance of the drift along shore can be seen at Timaru itself, where several acres of land have been reclaimed by this agency on the weather side of the breakwater, which has checked the northerly movement of shingle at that point. This check can only be temporary, as no possible human works can obstruct for long the action of an ocean-current. Further north, towards the southern end of the Ninety-mile Beach, the sea seems to be getting the best of the struggle, and the fringe of the old fan of the Rangitata and Ashburton Rivers is now being cut away. But further north still, when the Ashburton and, above all, the Rakaia Rivers have poured in their contributions of shingle, accumulation is rapid, as is proved by the presence of the great shingle-bank between Taumutu and Birdling's Flat, dividing the shallow waters of Lake Ellesmere from the deep sea. The shore-current has followed here a direct course across the mouth of a deep indentation of shallow water straight to the solid mass of Banks Peninsula. By it the northerly current is turned eastward into deeper water, and is thus rendered incapable of carrying its load of coarse material, so that this is piled by wave-action across the mouths of the bays facing south, which have now become the valleys known as Price's Valley and Little River. The fine detrital material is swept off into deep water, and some may find its way round the eastern side of the peninsula, and be dropped in the somewhat sheltered area on its northern side. The rate

of accumulation near Birdling's Flat must be extremely rapid, as old maps show that Lake Forsyth had in historical times a permanent outlet to the sea, and later still the seas used to break over the narrow spit of shingle which divided the lake from the sea ; and more recently, within the memory of the present writer, this bank has increased in breadth by several chains. This increase has taken place in spite of a probably downward movement evidenced by the presence of submerged forests in Lake Ellesmere.

The absence of any similar spit on the south side of Banks Peninsula between it and the plains is strongly suggestive that they have not been beneath the sea since the present land-surface was formed, as spits would have formed there if it had been depressed below its present level. The presence of a strong northerly current closely hugging the coast, and preventing the accumulation of silts and similar non-permeable beds interstratified with the shingle, explains the general absence of artesian areas to the south of the Rakaia.

The volcanic mass of Banks Peninsula is a fundamental factor in the formation of the Christchurch artesian area, since under its shelter have accumulated the finer sediments interstratified with coarser material without which artesian conditions would have been impossible. Immediately to the north of it the width of the "flowing well" belt is the greatest, and it narrows down as the distance north and south from it is increased. No doubt the northerly extent would be greater were the hills of North Canterbury further away, for the supply of artesian water falls off as they are approached, and fails altogether in their vicinity. The general structure of the area, as subsequent examination will show, is that of irregular beds of shingle and sand parted by clay-beds. They are not arranged in basin shape in accordance with the usual text-book diagrams, but in beds with a general slope to the east.

The water finds its way into the gravel-beds and flows seawards, and in all probability it has an outlet beneath sea-level to the eastward of the present shore-line. When a pipe is put down to the water-bearing stratum the water follows the path of least resistance, and if the surface of the ground is below the effective head of water the well will be a flowing one. This seems to be the principle on which the flow is dependent.

It is probable that during the formation of the artesian beds there has been a struggle between two forces—viz., the gradual sinking of the land, as evidenced by the presence of peat-beds several hundreds of feet beneath the present area sea-level, and the gradual building-up of the plain by aggradation. In a limited area parallel to the coast-line marine beds may have been laid down, and as sedimentation proceeded the area has been covered up by shingle from the rivers.

Present Surface Conditions.

The former conditions can be most easily realized by taking the present features of the area. In the sea off the present coast-line are beds of sand and mud ; in certain places, as the estuary of the Avon and Heathcote, patches of both occur in close conjunction. This estuary tends to silt up on account of the gradual increase in height of the half-tide flats by the action of *Zostera* and other halophytes entangling the finer sediment carried by the rising tide and incoming fresh-water streams. Thus over the sand-beds a coating of fine silt is deposited. Then again, along the coast and also in different places inland, probably marking old shore-lines, are rows of sand-dunes. Between them are usually peat-bogs of no great depth, the coating

of peaty matter rarely exceeding 2 ft. in thickness. These bogs rest on beds of clay formed by the sediment which has been deposited by rivers and tides, but principally by the latter raising the sea-bottom to the high-tide level. The area of bog and sandhill stretches back from the sea till the surface gravels of the plains are encountered, which have no regular boundary, but stretch out as tongues into the swamp and sandhill complex. An excellent example of this is to be seen at Addington, where a shingle-bank reaches down to the eastward, passes into Sydenham, and crosses Colombo Street South near the Sandridge Hotel. This shingle-deposit marks the presence of an old stream of gravel, and others are found in many places reaching out more or less into the swampy country. This is the general type of land-surface which is found all over the area. In those parts close to the sea sandhills and peat-bogs predominate, but on going away from the sea the shingle becomes more and more important, till it forms the whole present surface of the country. The land in all probability possessed similar surface-features when the water-bearing beds were being laid down.

General Conditions of Artesians.

In the publications of the United States Geological Survey there are numerous excellent papers dealing with the scientific aspects of the flow of water in artesian wells. In one of the earliest of these, entitled "Requsite and Qualifying Conditions of Artesian Wells" (5th Annual Report, 1883–84), Professor T. C. Chamberlin considers the general conditions which determine the occurrence and the flow of wells. Other papers of great interest are those by F. H. King, on the "Principles and Conditions of the Movements of Ground-water," and by Charles S. Slichter, on the "Theoretical Investigation of the Motion of Ground-waters," both in the 19th Annual Report (1897–98). In a paper on "Rock Gas and Related Bitumens" (11th Annual Report, 1889–90), W. J. McGee expresses the conditions governing artesian wells so very succinctly that I quote his actual words, especially as they have an important bearing on the conditions governing our own wells. He says (page 603), "In the inverse order of their importance, the requisites for artesian flow of water are—(1) Conditions of structure, (2) conditions of texture, and (3) conditions of supply. The most favourable structural condition is the arrangement of the strata in the form of a basin, as in the Province of Artois in France, from which the flowing well takes its name. The rain-water falling on the rim of such a basin percolates through the strata to its centre, and there rises through natural or artificial openings to a height depending upon the difference in altitude between the area of supply (or catchment-area) and the head of the well; but the basin structure is not absolutely essential, and artesian flows are obtained from uniformly inclined strata (such as those constituting the Atlantic coastal plain) when the catchment-area is elevated considerably above the well-head, or when the strata either diminish in permeability in the direction of the inclination or extend far beyond the point of outlet —*i.e.*, textural and other conditions may combine with structure to produce flow where structure alone is unfavourable. The most favourable textural condition is found when the porous stratum extends from the catchment-area to the part of the basin, trough, or monocline tapped by the drill, and is overlain (excepting in the catchment-area) by an impervious stratum. This condition, like the last, is not absolutely essential to artesian flow, since all rocks are more or less pervious, and if the difference between the

catchment-area and well-head is sufficient a slight flow may be obtained almost anywhere, but it is essential to abundant flow, and, indeed, to the slightest flow, unless other conditions are exceptionally favourable. The most favourable condition of supply is found when the porous formation rises from beneath less porous strata and forms the surface over a broad area."

After this general statement of the conditions governing artesian wells we must pass on to consider those which affect the particular area under consideration.

Extent.

The artesian area referred to in this paper consists of the belt of country which fringes the coast from the mouth of the Ashley River southward through Kaiapoi, Christchurch, Tai Tapu, Ellesmere, to the mouth of the Rakaia. Its length is nearly fifty miles, but its breadth varies considerably, being very narrow at the north and south, and reaching its greatest width in the neighbourhood of Christchurch, where it is about ten miles wide. Its inland boundary is roughly marked by the railway-line which runs from Christchurch north to Leithfield and south to Southbridge. In one or two places the area extends slightly over this approximate boundary, the artesian well farthest from the sea being at Islington, on the Main South Line, about eight miles from Christchurch.

Structure of the Area.

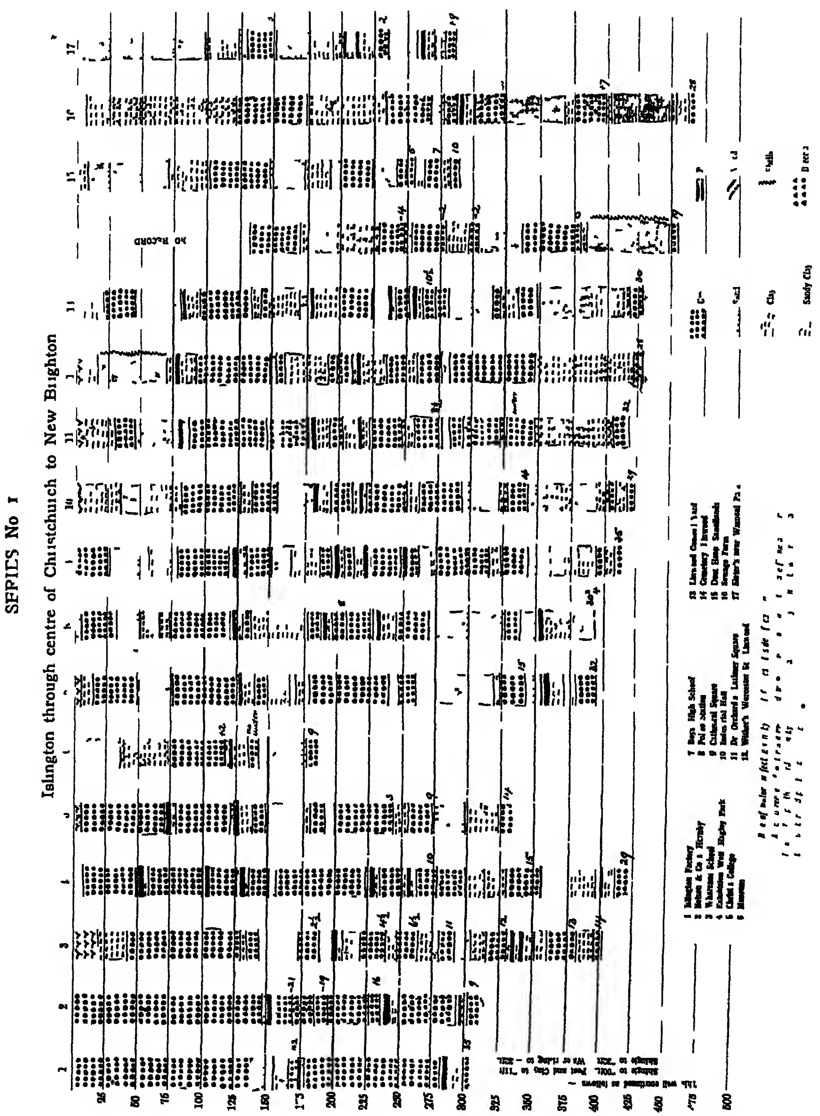
The structure of the artesian area has been arrived at by considering the records of well-sinkers and plotting the depths and character of the beds encountered on sinking. In order to show this, the records of a large number of wells have been drawn in a series of vertical sections. Of course, it is impossible to give the records of all the wells that have been examined, but a large number of typical ones has been selected on lines run in various directions through the area, so that a fairly accurate conspectus of the structure can be obtained. In drawing up these records no note has been taken of the height of the surface of the ground above sea-level in each case, since this would have necessitated careful levelling at the time of sinking. It was impossible to do this, as many of the wells were sunk over fifteen years ago; also, owing to excavations and filling in, the level of the ground in their vicinity has changed in the meantime in many cases, though by no great amount. In any case, the error arising from this neglect can be very slight, as the height of the surface of the ground over by far the largest part of the artesian area does not exceed 15 ft. above the sea, and its level is remarkably uniform. This omission does not affect to any marked degree the question of geological structure, although it does affect the questions of water pressure and flow. It is to be hoped that at a later date some information may be forthcoming on the purely hydraulic problems that the wells of the area furnish.

The sections exhibited on the plates will be taken in turn and their special features indicated.

Series No. 1.—From Islington to the Sea-coast at New Brighton.

(Plate IX.)

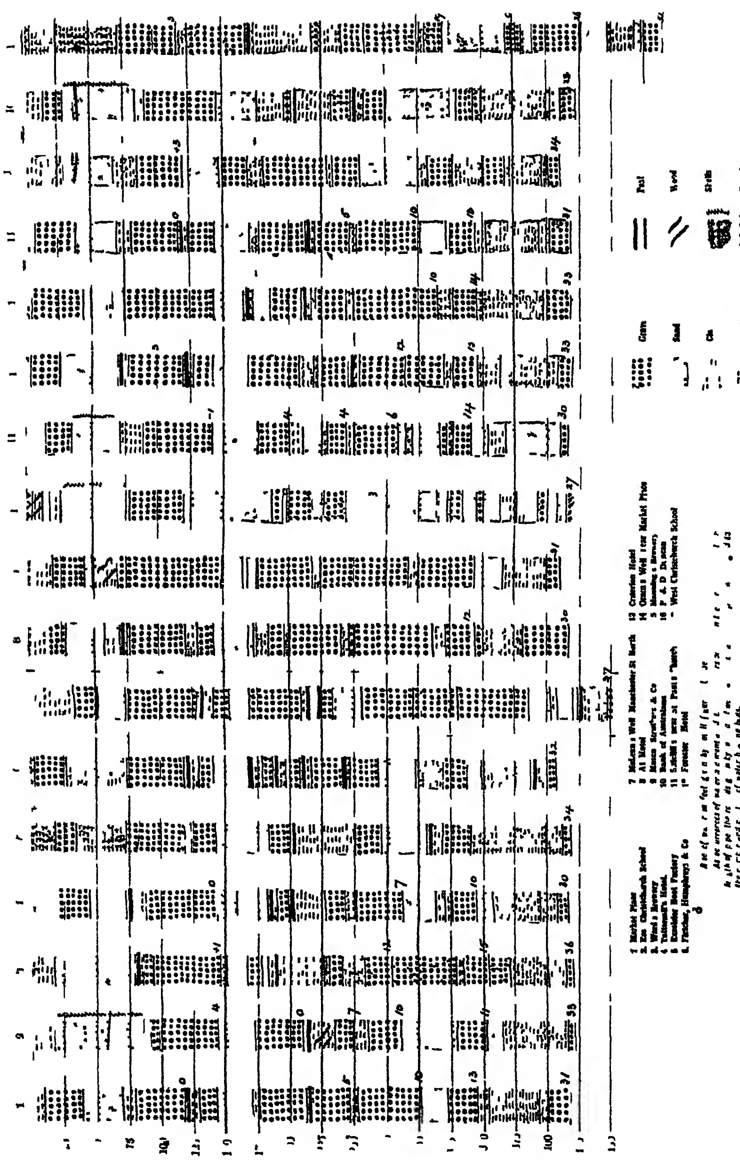
Islington is situated at an elevation of 112 ft. above the sea, and is the place furthest from the coast at which artesian water has been obtained. An examination of the section will disclose that the beds are not laid down in any markedly regular sequence, but are of alternating layers of coarser


SERIES No. 1
Islington through centre of Christchurch to New Brighton

Face p. 416.

SERIES No 2

Deep Wells Central Ward, Christchurch



and finer material, with occasional peat. There is a progressive diminution in the amount of gravel encountered in the bores on approaching the present coast-line. This is by no means uniformly true, as the Boys' High School well, in the western part of the city, shows a very large proportion of gravel to be present, a feature which is also shown to a minor degree by other wells in its vicinity—for example, the Christ's College, and the Exhibition well in Hagley Park. This exception does not, however, negative the statement that there is a general increase in the amount of shingle on going east. These beds must have been laid down where strong currents were in operation, due either to river or sea currents, the former in all probability: and they are almost certainly due to the aggrading action of a powerful stream on a land-surface. The presence of peat also proves that subaerial conditions obtained over the area while the beds were in process of being deposited. The sand and clay beds interstratified with them are in all probability principally of marine origin, since remains of shells are frequently encountered in them. Their association with land-beds proves that there was a struggle going on between the forces that tend to build up a sea-bottom to the level of the sea and to continue it as a land-surface above that level, and, on the other hand, a general sinking of the land, which is evidenced by the peat-beds now found so far below sea-level—600 ft. in the case of the well at Islington. It is apparent that at times the aggrading forces got the best of it. How far this depression of the land has gone on in excess of that already proved is quite uncertain, and only deeper wells will disclose the information.

The water-bearing beds of this section, as, indeed, is the case in others, are almost invariably composed of shingle. According to well-sinkers, water is frequently found all through these gravels, but the most prolific supply is obtained from just above the impervious layer below the beds; in fact, its general distribution throughout the gravel-layers in a particular well is looked on as an unpromising indication for a good flow being obtained from that bed. The overlying impervious layer is usually clay, but it may be sand or even more consolidated and less porous gravel.

The height to which the water rises is generally found to increase with the depth of the well, though in one or two cases the reverse is found in the case of a particular bed. This may be put down to friction preventing the passage of water through the bed. Owing to the level of the ground over a large part of the area being only a few feet above sea-level and sensibly uniform, there is apparently little difference in the height to which water rises on approaching the coast, but the condition of texture of the bed appears to be the controlling one affecting the height to which wells rise for a particular depth. In the part of the area to the west where the plains rise somewhat steeply the wells are non-flowing, although the pressure of the head maintains the water in the pipe at a fairly definite level, and it would flow, if it were possible to take it off, below the level of the ground. The water in the first stratum of the well at Islington rises only to 42 ft. of the surface of the ground—that is, the level of the water is 70 ft. above the sea.

Series No. 2.—Deep Wells: Central Ward, Christchurch.

(Plate X.)

This series of sections gives a record of a number of the deeper wells of the centre of the city, with one or two others added for purposes of comparison. They furnish the most detailed representation of any particular

locality available at present, and they suggest that when other areas are similarly plotted the minute structure of the area may be determined, and some of its apparent irregularities may be removed.

From this series of sections it will be seen that certain sands, sandy clay, and clay beds are persistent and regular over a fairly wide area. Well-marked beds of this type occur at a depth of between 40 ft. and 80 ft. below the surface, another between 150 ft. and 175 ft., another between 350 ft. and 400 ft. Similar, but le persistent, beds divide up some of the main gravel-beds into subordinate and irregular layers. From the occurrence of shells in certain of these beds it may be inferred that they are marine or aestuarine, although it is possible that some are not. It will also be seen that a bed of gravel, thick and continuous in one well, is frequently broken up in a neighbouring well by sand and clay beds. As nearly all these gravel-beds will yield artesian water, it is obvious that it is almost impossible to state the exact depth of the different water-bearing strata in any locality, as a particular water-bearing bed of one well may be divided up into a number of thinner beds in a neighbouring well, where, owing to different conditions of pressure, friction, and the supply of water, flows of varying amount may be obtained from what are apparently different beds, although they are really connected with one another. It is thus impossible to predict with any degree of certainty the number of water-bearing beds that will be encountered within a given depth, or that water will be met with at any particular level, though certain belts are extremely likely to contain it in one or more levels. It will be noticed that a very uniform and widely distributed water-stratum is found about the 400 ft. depth; all the wells from this show a marked regularity in the height to which the water rises above the surface. This is, in all probability, a stratum covered by marine or aestuarine bed, an occurrence which suggests that the conditions were uniform over a comparatively wide area.

This series of sections shows the presence of peat-beds, sometimes singly, and again divided by thin bands of clay and gravel. Remains of wood are also encountered.

The height to which the water rises in any particular well is also found to depend principally on the depth, although there are one or two departures from the rule, as mentioned in dealing with Series No. 1.

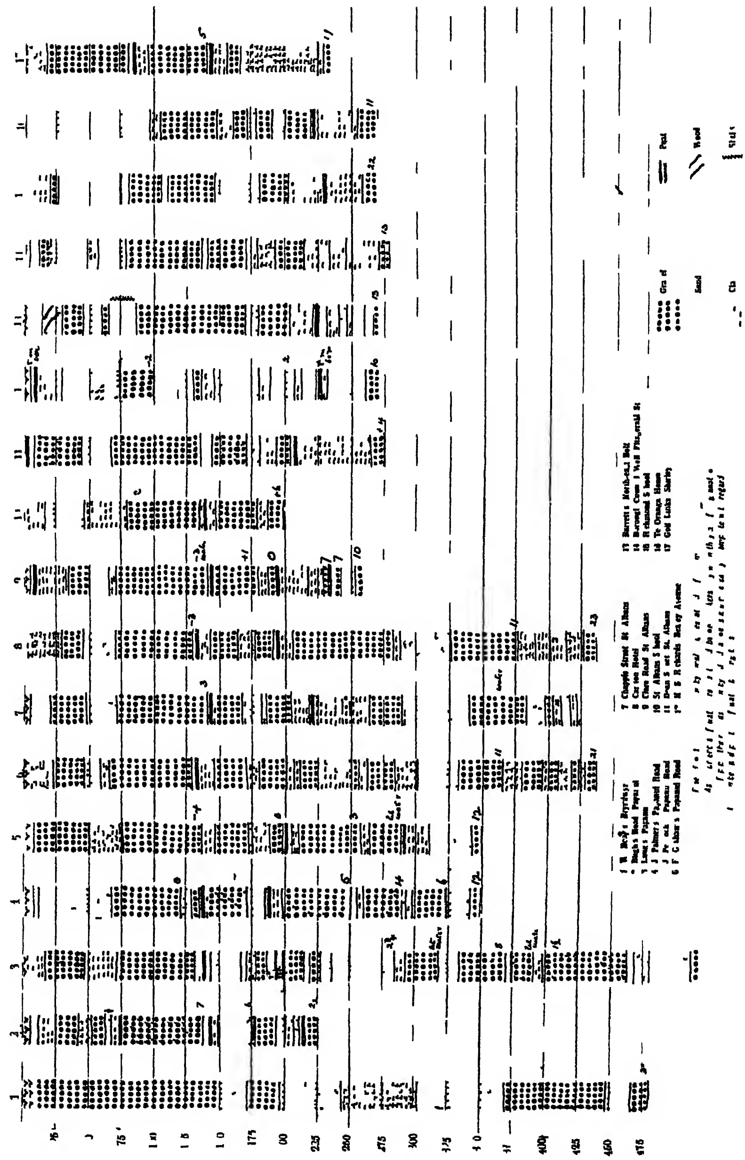
Series No. 3.—Papanui, St. Albans, Richmond, and Shirley.

(Plate XI.)

This shows the structure and character of the water-bearing beds in the district stretching from Fendalton, through St. Albans, towards the coast. The first well lies on the edge of the artesian belt, and shows, at all events in its upper levels, a marked predominance of gravel; but on going east the amount of gravel in the sections decreases, and finer detritus becomes more important. There is a certain element of regularity in the arrangement of the beds. A well-defined clay-bed extends almost all over the area, with an occasional coating of peat, and under it is a fairly regular band of gravel. Under this lies an extremely persistent bed of sand or sandy clay, which contains at times marine shells, thus showing that the sea stretched over the area at a comparatively recent date. This is succeeded below by a somewhat broken set of beds composed of gravel separated by peat and also by fine detrital matter; but in spite of the apparent irregularity there is an approach to order in the arrangement, and a more complete set of sections would show this absolutely. Even the sections as they

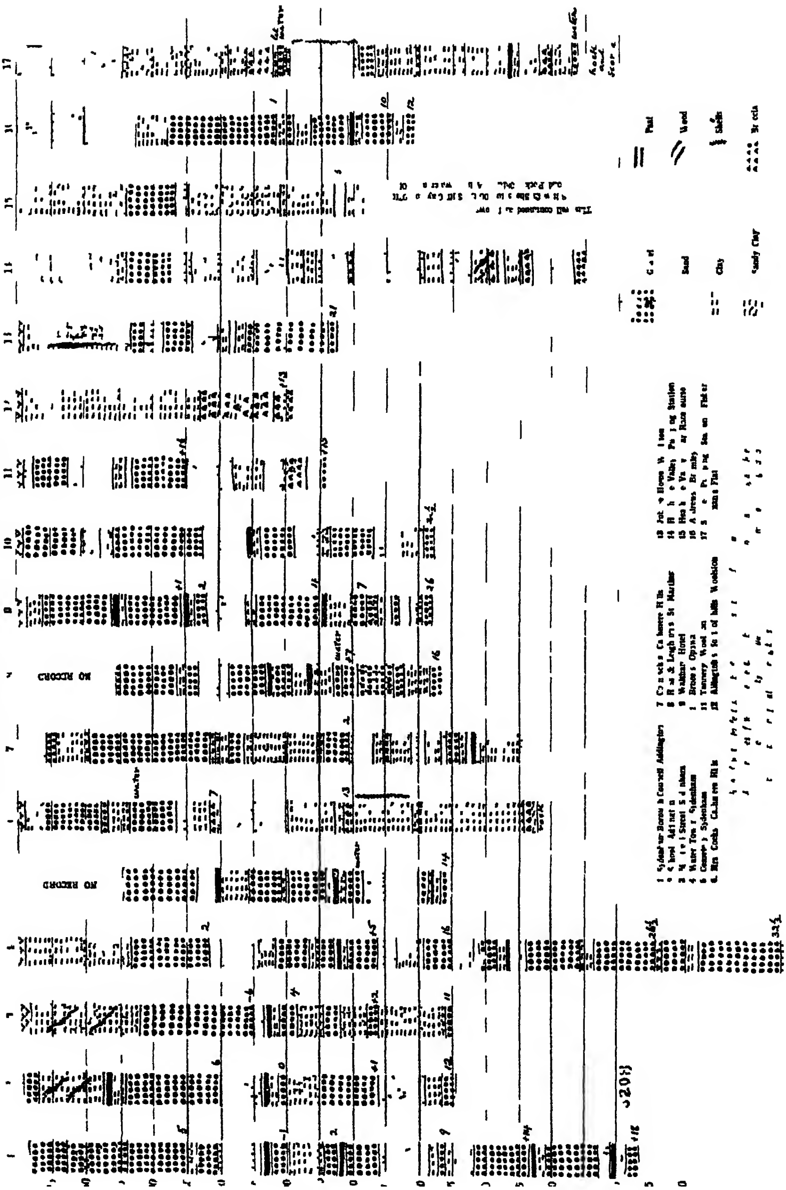
SERIES No. 3.

Papanui St Albans, Richmond and Shirley



SERIES No. 4

Sydenham, Opawa, Heathcote to Estuary



stand give a fair idea of the thinning-out and thickening of the same bed in different parts of the district. Below the belt where gravel predominates there is a set of beds composed of finer detrital matter, which would probably be continuous if the records of more deep wells were available. It will be noted also that there are very regular and widely distributed peat-beds, especially in the Fendalton and St. Albans area.

The series shows that there was a general struggle for existence between the land and the sea. The periods when the former got the best of it are indicated by the presence of peat, and perhaps by the gravel-beds, and the time when the sea stretched over the area is indicated by the finer-textured beds with their occasional shell-remains. The amount of rise in the wells increases, as a rule, on approaching the coast-line, and this may be put down to the better textural conditions near the coast. Instead of the water being distributed throughout the thick beds of shingle it is concentrated by the impervious beds into narrower bands, and so gives higher and stronger flows.

Series No. 4.—Sydenham, Opawa, Heathcote to Estuary.

(Plate XII.)

This series shows the structure of the belt of country which fringes the foot of the Port Hills and extends across the estuary towards New Brighton. The wells of special interest are those close to the hills, in whose records there is frequent mention of the presence of angular matter of volcanic origin. It is probable that the water supplying them comes from rain which falls on the Port Hills, and not from that on the plains. but more detailed work will have to be done before this statement can be maintained for certain. There is no doubt that the rocks of the hills exert a disturbing influence, since some wells which are sunk in their vicinity to beds of shingle yield no water, though a little distance further away similar beds at equal depths are prolific. These beds must be cut off in some way from the main artesian area. Others of them are down very close indeed to the underlying beds of volcanic rock, especially those near the present estuary. a fact emphasized by the record of the wells sunk by the Sumner Borough Council in their efforts to obtain water for the reservoir which supplies the borough. The ignorance of artesian conditions, as well as the unnecessary expenditure of the public money resulting therefrom, is thoroughly exemplified in connection with one well in the estuary near the Fisherman's Flat. After getting a poor flow of water at a depth of 416 ft., the boring was continued 41 ft. further, through layers of scoria and hard black basalt, evidently an outlying part of the rocks of the Lyttelton volcano, in expectation of getting a more plentiful supply. Needless to say, this hope was not realized.

The records of the wells near the estuary show that beds containing shells are met with very persistently, and it may be inferred therefrom that the conditions on the north side of that part of Banks Peninsula have not altered materially since the beds were first laid down—*i.e.*, the area has been aestuarine for a very long time.

This series contains the record of two very deep wells: the first sunk to a depth of 708 ft., near the old Heathcote Racecourse, in order to obtain, if possible, a supply for the Lyttelton Waterworks—an unrealized expectation; and, secondly, the well sunk at the Sydenham Water-tower, which reached a depth of 572 ft., and gave a flow of water from a depth of 550 ft., which rose 32½ ft., and was described by the well-sinker (Mr. J. W. Horne) as the largest flow he ever got. I believe that this is the deepest flowing

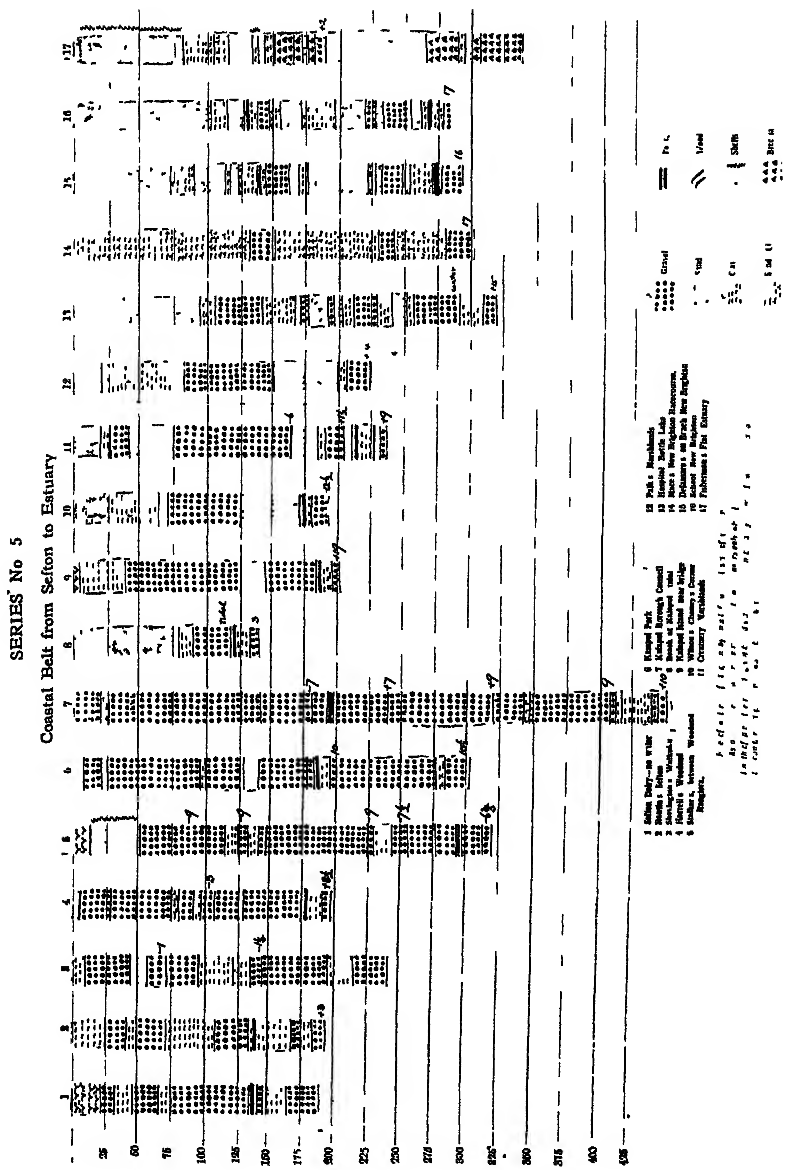
well in the Christchurch artesian area, the well at Islington, though sunk deeper, not giving a flow at the surface.

Series No. 5.—Coastal Belt: Sefton to Estuary of Avon and Heathcote.
(Plate XIII.)

This series gives a selection of wells from along the coastal belt reaching from Sefton to the north of the Ashley River, through Kaiapoi and New Brighton to the Port Hills at the estuary of the Avon and Heathcote. In the extreme north of this belt the supply of water is poor, but fairly good flows are obtained in Woodend and at Kaiapoi; nevertheless, the supply is both deficient in amount and in the height of rise as compared with wells in the immediate neighbourhood of Christchurch. The relative small height of rise can be readily seen by comparing the Kaiapoi Borough Council well, sunk to a depth of 450 ft., with deep wells in the middle of Christchurch. The Kaiapoi well gives a rise of only 10 ft. from that depth, whereas the Christchurch wells give a rise approximating to, or even exceeding, 30 ft. This well gave a flow of 50 gallons per minute at a height of 1 ft. when first sunk, an amount which compares favourably with deep wells further south; but the comparative smallness of supply is borne out in the case of other wells. Inland from the town the supply falls off considerably, for at Ohoka a well sunk to a depth of 374 ft. gave only a 2 ft. rise. In this case, however, the beds were almost exclusively of shingle, and the conditions of texture were decidedly unfavourable for the production of much artesian water. As a general rule, the beds of Kaiapoi and its immediate vicinity show the presence of a large proportion of shingle, from which it may be inferred that a large river has occupied the present position of the Waimakariri for a considerable period of time. Just to the north of Kaiapoi, and also to the south, beds composed of finer detritus become more important, till when the estuary is reached they are almost wholly of fine material, with an entire absence of shingle.

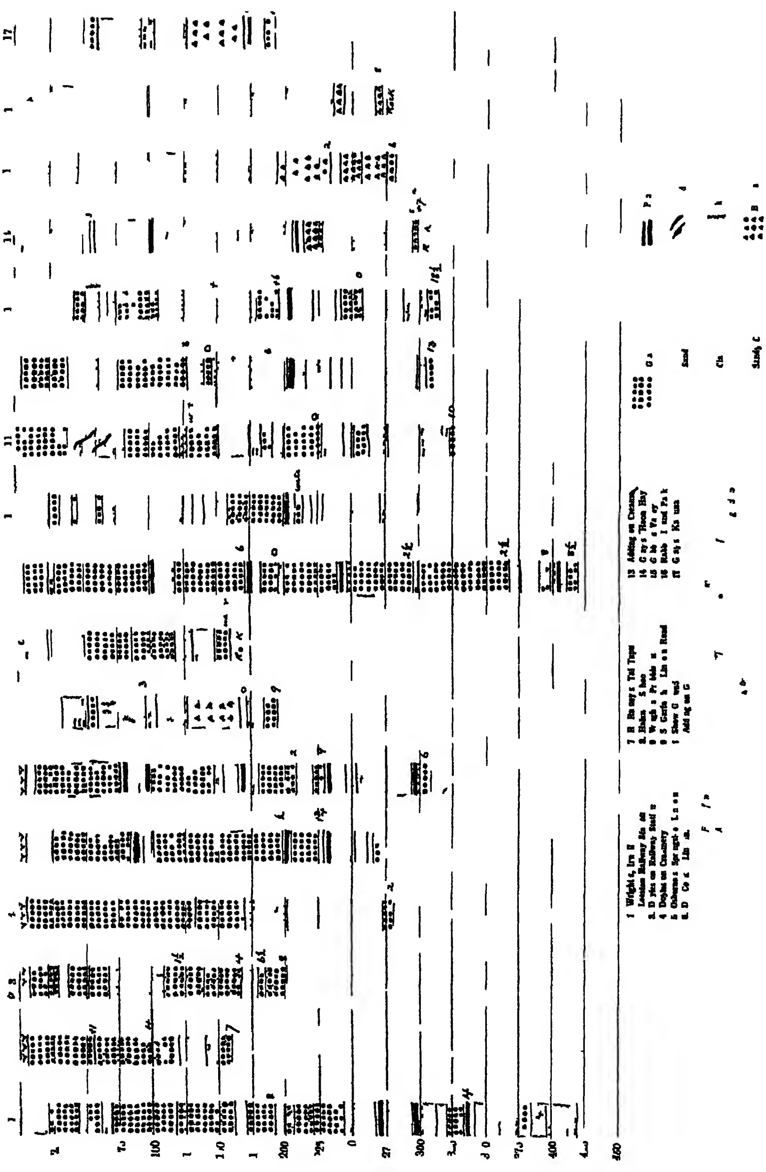
The two important factors controlling the conditions of texture of the beds are the presence of Banks Peninsula to the south and the delta of the Waimakariri in the north. This river has pushed out its delta beyond the general trend of the coast-line, and the finer material brought down is deposited on either side of the mouth. This accounts for the area of swamp immediately to the north about Woodend, and also the extensive deposits of fine material in the neighbourhood of New Brighton. An important factor in the latter case is the strong littoral current which runs down the coast during northerly winds. At that time the Waimakariri is usually in flood and heavily charged with sediment, so that the conditions are eminently favourable for the transport south of large quantities of detritus. A part of this is carried landwards, and ultimately forms dunes along the shore; and another part is deposited in shallow water offshore, or in estuaries formed behind the sand-dunes. Such aestuarine deposits are indicated in the sections given by the wells by the frequent marine shells which are brought up from the bores. These show that on the site of the present estuary of the Avon and Heathcote the conditions have been the same for a long period of time. No peat or other land deposits are met with in this part of the district till deposits of angular matter are reached at the base of the series, derived without any doubt from the disintegration of masses of volcanic rocks on the Port Hills.

The wells along this belt of country close to the shore rise in sympathy with the tide, and the water contains a high percentage of salt.


SERIES No 5
Coastal Belt from Sefton to Estuary

SERIES No. 6

Ellesmere north to Addington and Gebbie's Valley



Series No. 6.—Ellesmere North to Addington and Gebbie's Valley.

(Plate XIV.)

This series gives a selection of wells from the district round Lake Ellesmere. Its special features are the marked preponderance of gravel in the upper beds in the southern parts of the area and the comparatively poor flows of water that are met with even in deep wells. The requisite arrangement of beds seems to be absent or but slightly developed, a condition which occurs in other cases where the distance from Banks Peninsula increases.

A very interesting part of this area is that lying along the base of the hills in the neighbourhood of Gebbie's Valley. The beds here are almost wholly of sand and sandy clays, as is shown by the sections numbered 15, 16 and 17, which may be taken as typical; they also contain a fair proportion of angular volcanic matter, and thus resemble those on the north side of the peninsula.

At Teddington, just over the pass at the head of the valley, and within the basin of Lyttelton Harbour, there is another system completely cut off from that on the outside of the hills by the slates and volcanic rocks which form the western part of the old crater-ring of the Lyttelton volcano. It has been pointed out by Page and Prideaux in a paper entitled "Notes on an Artesian System at the Base of the Port Hills" (Trans. N.Z. Inst., vol. 33, p. 335, 1901) that these wells, and also those at Gebbie's Valley, present some decided differences from those of the plains, in that they contain a much higher proportion of chemical salts, notably chlorides, as well as exhibit a higher temperature than those of the Christchurch area.

It is very probable indeed, as pointed out in the paper just referred to, that the Gebbie's Valley wells belong to a different system from that on the plains, and the conditions governing the flow of water will be in that case very similar to those which occur at Teddington. In both the structure of the beds does not seem to be at all favourable to artesian flow, but conditions of texture appear to be the controlling factor.

A well which shows a relation to these is the fourteenth on the series, sunk near the foot of the Port Hills, at Hoonhay. This gives a flow of only $4\frac{1}{2}$ gallons per minute, and the water-bearing stratum is a layer of scoria lying on solid rock. The water has in all probability followed the surface of this rock down from higher levels on the Port Hills, and the well is quite distinct from the Christchurch artesian system.

Level of the Water in the Wells.

The height to which the water rose from the various levels in each well at the time of sinking is given in a small figure placed near the vertical sections at the depth at which the water was encountered. The surface of the ground is taken as the datum-line, and the height above this is reckoned as positive and below it as negative; the latter applies to non-flowing wells and to beds which do not yield a flow at the surface. These records furnish a basis for determining the amount of fall in levels which takes place after a well has been flowing for some time, a fall due partly to the fact that all wells go down slightly after a short period of time, even if they are not interfered with by others, and also to the fact that wells affect each other materially if they happen to be sunk so as to cause overlapping of the cones of depression which surround each well. The fall in level of the wells has been very rapid since they were first sunk in the district.

In his paper entitled "The Behaviour of Two Wells at the Canterbury Museum" (Trans. N.Z. Inst., vol. 28, p. 654, 1896) Captain Hutton states that a fall of from $2\frac{1}{2}$ in. to $2\frac{3}{4}$ in. per year has taken place in the case of first-stratum wells, and as much as $5\frac{1}{2}$ in. per year in the case of second-stratum wells. Comparing Captain Hutton's record of the height of the Museum well in 1895 with its height now, it is found that it has fallen off $53\frac{1}{2}$ in. in the fifteen years which have elapsed, thus giving an average yearly drop of 3·6 in. It is therefore falling off at a slower rate now than when Captain Hutton made his observations. In the paper just cited Captain Hutton also gives his observations on the height of the wells relative to the weather-conditions, &c. He notes the rapid response to rain; an occasional rise, apparently inexplicable on any known cause; a marked evening rise, which he attributes to a lessening of the call on the wells towards evening. He failed to find any tidal effect or any trace of variation in sympathy with floods in the Waimakariri.

These observations are being continued at the present time by the author, and also by Dr. Hilgendorf, of Lincoln College, but it is too early to make any definite statement as to their trend, except that the influence of rain and the existence of the evening rise are undoubted. It was hoped that a variation in sympathy with the barometer might be detected, which might explain the evening rise to a certain extent, and also the non-response of floods in the Waimakariri, which usually come at a time of low barometer. It is possible that the effect of floods in the Waimakariri may be just sufficient to mask the effect due to low barometer, and the isolation of the two separate effects may be a matter of considerable difficulty. The present author has received from very reliable observers so many authentic statements of the influence of the Waimakariri on rams and wells that the idea cannot be set aside as quite without foundation, and further observations are necessary to establish or disprove it. The undoubted effect of the barometer on the flow of wells must also be taken into account, and future observations may settle the question. At the same time, it must be admitted that the observations at the Museum may lead to no very definite result, owing to the disturbing influence of neighbouring wells, but much more may come of those which are being made at Lincoln under the direction of Dr. Hilgendorf, since the wells there are comparatively isolated.

The greatest rise above the surface of the ground in the wells I have examined is that of a well in Manchester Street North, which reached as high as 37 ft. from a 451 ft. level; but a large number of others give a height nearly as much as this when sunk to about the same depth. As a general rule, the height increases with the depth, but there are a few cases where variations in permeability seem to exert a neutralizing effect on the depth.

Amount of Flow.

The amount of flow per minute is very variable, and lies between zero and 100 gallons, and it is possible that greater flows occur of which I have no record. As a general rule, the quantity is greater at the deeper levels of each well, though with marked exceptions. The well just cited above as giving a very high rise yielded 40 gallons per minute at the surface from a bed 451 ft. deep, a flow of 20 gallons from one 386 ft. deep, but one of 60 gallons from the 296 ft. level, thus showing clearly that the amount does not altogether depend on the depth. I am informed by Mr. Osborne

that such anomalies are frequent. The quantity falls off naturally if the well be tapped at a height above the ground, but in certain cases a very considerable flow is obtained even at a high level. Observations have not been made to see if the diminution of flow follows the law stated by Slichter in the paper cited previously, but it is hoped that they may be carried out.

It is evident that not only the depth but the permeability of the strata and the amount of supply affect the yield from any particular well. The well-sinkers say that the best flows are obtained a little above the lower boundary of the water-bearing stratum, and, further, that where the water is distributed throughout a water-bearing bed the flow is always poor. These facts tend in the direction of the idea that there are well-defined layers of water percolating, probably at a somewhat rapid rate, through the porous gravel-beds of the area. When one considers the number of wells, the large amount which flows from some of them, and the great waste of water that is going on continuously, it will be readily realized that they must derive the supply originally from some very prolific and constant source, and one which is not very materially diminished by the enormous tax on it.

SOURCE OF WATER.

The water which supplies the wells appears to come from two sources—viz., the rainfall on the plains and the underground percolation through the shingle from such rivers as the Waimakariri. That the first source is undoubted is proved by the falling-off in the amount of water supplied by the wells during a period of dry weather, and their immediate recovery after rain. On one occasion the level of the water in the well at the Canterbury Museum jumped up 6 in. after several days' rain. The same effect was noted by Captain Hutton. The response is so marked that there is no doubt of the source of the supply, nor that the permeable beds outcrop but a short distance—probably a few miles—from where the wells are sunk. However, as the rainfall over the Canterbury Plains in the neighbourhood of the artesian area is comparatively low, and has an average of about 25 in. per annum, with a minimum of 14 in., recorded to date, it is evident that this amount could not furnish a supply sufficient to satisfy the great drain on it and keep fairly uniform, were there not some more reliable and constant source. The only satisfactory explanation for this main supply is that there is a very large amount of percolation through the shingle of the plains from leaks in the river-beds, which finds its way across the outcrops of the permeable beds and thus contributes towards the artesian supply Such leaks do undoubtedly occur, and during dry seasons a very large proportion, if not all, of the water in certain of the shingle river-beds is flowing underground. At a small depth there is usually an abundant supply, even when they are perfectly dry on the surface, and it takes but a slight shower of rain to make such a river again flow on the surface. In some of the rivers, like the Selwyn, the water disappears completely from sight even during normal seasons, to reappear miles lower down at the surface where the underlying beds are not so permeable. Many springs also occur along a belt which runs approximately through the place where the Selwyn water comes to the surface parallel to the coast-line and near the upward limit of the known artesian area. It is probable that the containing impermeable beds of clay and hard sand reach their furthest

westerly limit about that line, though, by sinking deeper wells still, they may be found to reach much further west at greater depths.

It is absolutely certain that water sufficient for the supply flows through the shingle. A statement has been repeatedly made to me by reliable persons that their wells flow much better during and after a nor'-wester. Accepting these statements as true, though my observations on the Museum well do not confirm it, the explanation would be that during nor'-westers the rivers are high, owing to heavy rains and melting snows on the main ranges to the west, and so an additional supply would be expected in the underground streams formed by percolation from the river-beds, and therefore the wells would respond with an increased flow. If the observations on which this conclusion is founded are satisfactory, it would tend to confirm the idea that the major part of the water in the artesian area comes from underground streams which reach the edge of the outcrops of the clay-beds occurring on the eastern fringe of the plains in the neighbourhood of Banks Peninsula.

Tidal Wells.

Along the shore-line the height to which water rises is affected very markedly by the tide; for example, at New Brighton, according to observations carried out by the author, the level reached by water standing in an open pipe varied during a tide as much as 18 in. in the case of a first-stratum well (depth, about 144 ft.), while a second-stratum well (depth. 280 ft.) was only affected to the amount of 10 in., both wells being a few yards away from the high-water mark and slightly above it. The influence of the tide on the wells is noticed all along the coast from north of the mouth of the Waimakariri nearly to the mouth of the Rakaia, and its effect is felt inland for a distance of three miles in the neighbourhood of Christchurch, with a gradually diminishing amount as the distance from the sea increases. It is impossible to tell the exact limits of the influence of the tide, owing to local and variable causes masking it when the amount is small.

It is also noteworthy that these tidal wells are salt. Near the shore the water from the first-stratum wells is so salt as to be unpleasant to drink, while that from the second stratum is less salt, the amount of saltness falling off with greater distance from the sea. No data are at present available as to the amount of saline matter present in these wells, but this will be furnished in a subsequent paper. In certain cases, too, wells sunk some distance from the sea are distinctly saline immediately after being sunk, but lose their salinity after an interval of a few weeks; but this does not apply to those near the shore, which are permanently salt.

Natural tidal wells are known from other parts of the world, and I have seen a reference to similar artesian wells round the shore of the Bay of Tokyo, in Japan. I cannot find the article on this subject which drew my attention, but, as far as I can remember, the writer attributed the variation in level in this case to the loading of the surface of the ground by an additional weight of water at high tide, and cited experiments as to the effect of artificial loading on the height of wells. As far as I can recollect, the two cases are somewhat parallel; but the presence of salt water in the Canterbury tidal wells suggests that these wells have access to the sea, which is not explained by the theory just mentioned.

The combined effect of the tide and the presence of salt may be explained if it is understood that the water-bearing stratum has an outcrop under

the sea, and that there is a possibility of mixture occurring between the salt water and fresh under these circumstances. It will generally be thought that an outlet under the sea would at once destroy the possibility of getting artesian water near the shore, but I think it can be shown that even with an outlet the presence of a counterpoise of sea-water may be almost as effective as an impermeable bed blocking the outflow. The conditions will resemble to a certain extent those of the well-known laboratory experiment of the U tube, with its branches filled with unequal lengthened columns of liquids of unequal density which balance one another. It is perfectly possible to draw off a supply of the lighter liquid from a level above that of the heavier liquid. If now we suppose that salt and fresh water are the two liquids, then if we have a constant supply of fresh water carefully introduced it will be possible to draw off a continuous supply of fresh water at a higher level. Let us now apply this experiment to the circumstances on the shore of the artesian area—say, at New Brighton. In this case the rise of the tide is about 6 ft., and the depth of the first-stratum wells near the shore about 144 ft. We may suppose, therefore, that the water-bearing stratum outcrops at an approximate depth of 144 ft. below low water. Taking the specific gravity of sea-water as 1·025, the length of a column of fresh water which would exactly balance this would be 144 × 1·025—that is, 147·6 ft. So that a well sunk at the level of low water and supplied with a continuous amount of fresh water from inland would flow at about 3 ft. above the surface. If now the tide rises, the well will rise with it. Theoretically, a rise in the tide of 6 ft. with no admixture of the liquids would cause the well to flow 6 ft. higher. The New Brighton wells do not vary as much as this, a discrepancy due to a certain extent to the friction which obstructs the rapid flow of water through the beds, thus diminishing the effective pressure, and also to the admixture of the salt water with the fresh at the bottom of the well, which also reduces the difference between the level of the sea and that of the wells. This mixture must take place owing to the disturbed conditions at the bottom of the well, due principally to the movement which must take place as the water is drawn off. This explanation accounts for the mixture of salt water with fresh in the case of wells near the shore, and also the falling-off in saltness as well as in the tidal effect on increasing the distance from the shore.

CONCLUSION.

It is hoped that the diagrams given with this paper may be of some interest and use to the general public, as they afford a certain amount of information as to the depths at which the water-bearing beds are to be found, and seeing that these records are put into such a form as to be readily understood.

The main results of this preliminary investigation of the area are to demonstrate,—

(1.) That the geological arrangement of the beds is not so irregular as was anticipated at first, but that certain probable marine beds are persistent over considerable areas.

(2.) That the water-bearing beds, being gravel, and in all probability laid down on a land-surface or by the agency of strong and varying currents, are liable to great variation in thickness and also to be split up by intercalated sandy or clay beds. This increases the number of water-bearing

beds, and militates strongly against accurate predictions being made as to the precise depth at which water will be struck in any particular locality.

(3.) That the level of the land was gradually depressed for at least 600 ft., probably much more, while the beds were being laid down. This fact has considerable bearing on the explanation of the advance and retreat of glaciers within recent times, and also on the formation of terraces in the Canterbury District. In the face of the positive evidence for depression, the explanation of the formation of the river-terraces as a result of elevation must be taken with great reserve, and the present writer does not believe that elevation was the determining cause for their formation. The reason for the depression of the land is uncertain. It may be the result of a loading of the crust with detritus, or it may be due to some great crustal movement whose prime cause can hardly be indicated at present, considering our scanty knowledge of the changes which affect the body of the earth as a whole.

These are the main results of this inquiry up to the present, but there are several further lines of investigation which could be indicated, such as (1) the chemical properties of the water in relation to the geological conditions, (2) the various interesting hydraulic problems dependent on pressure and supply, and (3) the purely geological one of the actual order and arrangement of the various beds in their bearing on the general mode of construction of delta deposits.

Art. XLI.—*The Effects of the Disappearance of the New Zealand Bush.*

By Archdeacon Walsh.

[*Read before the Auckland Institute, 26th September, 1910.*]

On the 19th July, 1896, I read before the Auckland Institute a paper in which I attempted to trace the principal causes which are combining to produce the extensive and rapid disappearance of our native forest. This was followed in 1898 by another, in which I endeavoured to forecast what will be the future condition of the forest when something like a balance shall have supervened between the destructive agents on the one hand and the resilient powers of nature on the other. It may be well to follow up the subject a stage further, and try to point out some of the more notable effects which are already following on the deforestation of the country, and which, as time goes on, must increase in an accelerating degree.

In order to present the matter as clearly as possible I shall recapitulate once more the argument of the first paper:—

The two principal destructive agents, besides the axe of the bushman, are cattle and fires. Any one of these acting alone is sufficient to do a great deal of damage; but when they all act in conjunction—as they generally do—the destruction is greatly accelerated and intensified.

The greater part of the forest below a moderate altitude, throughout both Islands, is an open cattle and pig run in which by the browsing, trampling, and rooting of the animals the undergrowth is gradually destroyed, the surface-roots lacerated, and the soil trodden into mud, which in summer hardens almost into a bed of concrete. The consequence is that the larger trees, deprived of their accustomed nourishment and protection, gradually grow thin and open at the top; the ground is covered with the fallen leaves, and the *débris* of centuries, now exposed to the sun and wind, is dried to tinder, when the whole place is ready to be swept by fire, which sooner or later is sure to happen.

In thickly settled districts, and in those where timber-getting is carried on, the destruction is, of course, most rapid and complete, as every clearing, timber-working, and road-line forms a starting-point for the fires, which spread into and kill some portion of the standing bush. And as wherever the fire has once passed it will pass again while there is anything to burn, before very long, in districts where clearings are frequent, the whole bush is consumed, with the exception, perhaps, of that which stands in the lower and damper situations, or which from the conformation of the country is protected from the sweep of the flames. In this way, in a comparatively few years, immense areas have been destroyed in many of the more settled districts, while in others the work is going on more or less rapidly and completely, according to the nature of the bush and the climatic and other conditions.

Now, it does not require a great deal of intelligence to understand that such a radical alteration in the conditions of the country as is involved in this wholesale destruction must result in very serious consequences, whether for better or for worse. So far, unfortunately, I think it must be admitted, the consequences are very largely for the worse—as I shall endeavour to show.

The effects of the disappearance of the New Zealand bush may be roughly classed under two heads—viz., climatic and topographical.

CLIMATIC.

(1.) *Rainfall.*

There is a widespread popular opinion that rain is attracted by standing forest. Much speculation has been expended on this question; but, so far as I have been able to learn, it has not led to any very satisfactory results. To a superficial view, the theory seems to be borne out by the fact that there is generally a greater rainfall in forest-covered districts than there is in open country—as, for instance, the west coast of New Zealand, which is heavily wooded, is much wetter than the country along the east coast, which is comparatively dry. But this is really to mistake cause for effect; and the truth is, so far as it can be ascertained, that the amount of precipitation is at least mainly determined by the topographical conditions of a country, apart from its vegetable covering—that, in fact, the rainfall is not caused or increased by the presence of the bush, but that the growth and conservation of the bush are promoted by the excessive rainfall. This contrast in the hygrometrical conditions of the east and west coasts is very easily accounted for. The moisture-laden winds from the ocean, meeting the steep face of the chain of hills which—with an occasional break—extend along the west coast of both Islands, are thrown up into a colder stratum, with the result that the moisture is immediately

condensed, and falls in the form of rain on the upper parts of the elevated ground. After passing along for a few miles the moisture is, as it were, strained out of the air, so that the same aerial current that brings rain to Hokitika, for instance, becomes a dry wind by the time it reaches Christchurch.

(2.) *Winds.*

But though the removal of the forest may not result in the diminution of the rainfall, it may nevertheless have some very marked effects on the climate. One of the principal of these is the increasing strength and dryness of the winds that blow during the summer months, and which have become more and more injurious to vegetation. The cause is not far to seek, and its operation may be observed in any part of the bush district to the north of Auckland, and especially in the high rugged country which was once the home of the kauri. A few years ago, with the exception of some comparatively insignificant areas, this extensive district was covered with forest from shore to shore. The warm winds, charged with moisture from the ocean, passed gently over the country without injury to the most delicate plant—in fact, they were just what the native vegetation required for its full nourishment and growth. But with the destruction of the forest there came a change which is being intensified every day. The removal of the kauri, and the settlers' clearings, made way for the forest-fires; and as these did not confine themselves to the portions artificially cleared, but worked their way into the standing bush, in a comparatively short time the greater portion of the country, especially along the backs of the high ranges, became denuded. Unless this bared land is immediately brought under cultivation, which is only done in the more fertile spots, it soon becomes covered with a clothing of fern and tea-tree scrub: and this in its turn is overrun by fire every dry season, each fire consuming some of the humus in the soil, and gradually reducing the land to barrenness, until at last the scrub becomes so light that it affords no protection to the ground from the sun's rays. The consequence is that on every clear day from December to March the air is so superheated by the radiation from the baked soil that it rises in a column to the heavens, and a current is established to draw in a fresh supply from the lower levels. Every gully becomes a funnel up which the wind rushes in a tearing blast, becoming more and more desiccated as it travels; orchards are blighted, grass is parched up, and crops are prematurely ripened; while the remnant of the bush becomes so dried up that it is ready to be swept by the first fire that comes along. Old settlers will tell you that the seasons have changed of late years, and they fondly hope that after a certain cycle has run its course the old state of things will return; but this will never happen until, by judicious planting and cultivation, something like the old conditions have been re-established.

But the effect of the wind is not only felt on the high lands. The draught commences at the coast, and is drawn up the estuaries and the long winding valleys that are a feature of the topography of many parts of both the North and the South Islands. On the Hokianga River, which has a navigable course of over twenty-five miles for large vessels, and traverses an extensive settled district, it is noticed that the summer winds are much more violent than they were when the place was first occupied. Orchards and vineyards require more protection: while along the banks the native bush has a parched and storm-swept appearance that it never had in former times.

(3.) *Blizzards.*

In certain parts, chiefly on the level lands along the west coast, and notably on the long stretch between Cape Egmont and Wellington, a new trouble has arrived in the shape of the "blizzard," the name signifying in America a snow-blast, but which has in the locality under mention been applied to the salt storms that drive in from Cook Strait. The district has always been a windy one, as may be seen by the growth of the old native trees still standing, the weather side of the karakas, mahoes, &c., being shorn off, while the tall trunks of the rimus and kahikateas lean out of the perpendicular. But with the removal, partly by the axe and partly by decay induced by the rumination of cattle, of the belt of scrub and small bush that stretched along the coast the conditions have altered greatly for the worse. The salt spray that was once stopped by this natural breakwind is now carried for miles inland, and is not only severely felt by stock, but is most injurious to almost every kind of vegetation. An object-lesson might have been watched in the gradual destruction of an extensive plantation of macrocarpa-trees made some thirty-five years ago near Hawera. These for some time did very well. They grew uniformly to a fair height, and promised to make a most useful shelter-belt. But in proportion as the natural bush to seaward disappeared they were no longer able to stand against the salt blasts. Swept by successive blizzards, they gradually perished, until a few years ago a picture in the *Auckland Weekly News* showed the last survivor, a storm-beaten dying wreck.

This is, of course, an extreme case; but the same thing may be seen more or less on any exposed part of the coast from which the natural protection has been removed.

(4.) *Frosts.*

"We never used to have these heavy frosts before the emigrants came in," said the old Taranaki settlers some twenty-five years ago, as they thought of the golden days, when the "garden of New Zealand" was fenced off from the rest of the world by forty miles of standing bush. The statement was not much exaggerated, as the forest, which was particularly tall and dense, not only sheltered the country from the violence of the south-easterly winds, but had the further effect of modifying the temperature to a great extent. But when the land was thrown open for settlement the bush disappeared with remarkable rapidity; the cold winds swept unchecked over the bare land, and for some years past the frosts have come down to the water's edge.

Hokianga used to claim a subtropical climate, and in a few sheltered spots the banana may still be found ripening in the open. But these spots are daily becoming more rare. Since the general disappearance of the forest a stream of chilled air flows down the long tributary valleys, and not only jeopardizes the growth of the more tender plants, but materially affects the remnant of the native bush. In many cases one sees the outstanding puriris—an interesting survival from the rumination of the cattle—quite seared and blackened, while the ashen hue of the withered taraire-trees shows that the frosts, once in this region confined to the flats, are now reaching up the hillsides. In fact, it is safe to say that with the disappearance of the bush the frost-belt has moved many miles further north.

(5.) *Cold Winds and Droughts.*

During late years the dairy industry has been one of the most popular and profitable industries of the bush settler. Every acre or two of grass represents a cow, whose yield of milk helps to swell the monthly cheque from the factory; and so, regardless of everything beyond the immediate return, the bush is cleared away as fast as possible, and the land laid down to pasture. If it were only a question of a dairy farm here and there amid the surrounding bush the results might, perhaps, justify the policy; but when a large area is wholly occupied by dairy farms unlooked-for consequences are sure to follow. To take one instance where the whole thing has been worked out to its logical conclusion: Some forty years ago the Settlement of Okaihau was formed on a piece of land between the Bay of Islands and Hokianga, covered for the most part by a dense forest, then known as the Nine-mile Bush. Through the centre ran a broad level ridge—almost a tableland—800 ft. above sea-level, which fell away on both sides in sharp ranges and deep gullies to two tributaries of the Hokianga River. When the first clearings were made the soil seemed to be of quite unusual richness: droughts were unknown, and every variety of crops grew with the greatest luxuriance. Attracted by the fertility of the soil and the advantages of the situation new settlers flocked in, and before long practically the whole of the land was cleared. Then, when it was too late, the evil of this wholesale denundation began to be apparent. The wind drew up the bared gullies and swept unchecked across the tableland—in bitter squalls in winter, and in scorching gales in summer. Droughts became common, and the smaller streams dried up for want of protection at their sources. The very character of the soil seemed to change from a rich, deep loam to poor, light stuff; cropping was almost abandoned, the grass grew scantier every year, and the whole settlement now carries less stock than it would do if a reasonable proportion of the bush had been left standing.

Topographical.

But serious as are the effects on the climate caused by the removal of the bush, they are nothing to those which are produced on the topography of the country. Of these some of the most disastrous are those which result from floods.

(1.) *Floods.*

Floods have doubtless been always prevalent in New Zealand; with its peculiar geological formation and its abundant rainfall it could not be otherwise. But with the removal of the bush they have assumed a form unknown before, both in regard to their magnitude and their power of destruction.

In its virgin state—before it is invaded by cattle—the New Zealand bush forms a natural storage for rain-water, and supplies an effective safeguard against excessive floods. Even in the most torrential downpour a large proportion of the rain never reaches the ground. The dense canopy formed by the tops of the trees breaks up the heavy drops into a fine dew, part of which is at once absorbed by the foliage. Of the rest, some is caught by the epiphytes and parasitic plants that clothe the limbs and trunks, or by the ferns and mosses and seedling plants, and the thick coating of humus, the decayed logs, and fallen leaves that cover the floor, where it is held in suspension till evaporation takes place. And here it may be

remarked that in the regions in which there is the greatest amount of precipitation nature has provided, in the thick turfy mould, as well as in the denser growth of the ferns, mosses, &c., a proportionately greater vehicle for the absorption and retention of the moisture. A considerable quantity of the water soaks into the soil, to be taken up as it is required by the roots of the growing trees, or to filter down to supply the springs that feed the head-waters of the streams; while the remainder—but a small portion of what has left the clouds—trickles gently down to the nearest outlet.

The removal of the forest quickly changes all these conditions. The first thing to happen is the erosion of the surface. No longer held back by the vegetable growth, the storm-water flows off the hillside like rain off the roof of a house, carrying away the ashes of the burnt timber with what is left of the rotted humus, channelling the lighter soil with frequent water-cuts, and bodily removing the most fertile portions. Then, as the network of roots decay, landslips occur in the steeper places—it is not unusual for a whole hillside to slide away into a gully—when the *débris* will be swept down, scouring the bed and sides of the creek, and covering the land below with a deposit of rocks and clay. When the ground affected forms part of a mountain district of large area, in which the creeks have a long course and several branching confluents, it often happens that the *débris* from a side creek or blind gully will form a temporary dam in the bed of the main stream. If this occur while heavy rain is still falling, a lake is immediately formed by the water from the hills above; and before long the obstruction carries away, when all the mineral detritus, together with the wreck of the ruined forest, is borne down by the foaming torrent to spread destruction below. Just such a catastrophe occurred among the Tokatea Ranges in 1882, when every bridge in Coromandel was carried away and kauri logs were stranded in the main street.

The most destructive floods occur when the water from an elevated region has to traverse a level country before reaching the sea, and the longer the course the greater is the damage. The floods which inundated the City of Paris in December last year (1909) are a case in point. The water was supplied by the unseasonable melting of the snow on the lofty plateau of Langres, where the River Seine takes its rise: but the fact that much of the plateau had been recently cleared of forest caused the water to run down much more quickly than it would otherwise have done, when the winding channel through the level country was unable to carry it off.

An instance more familiar to most of us is that of the great floods that took place in the Hawke's Bay and Palmerston districts in 1893, and again two or three years later. Phenomenally heavy rains had fallen along the watershed inland and down to Cook Strait. Every creek and river was flooded to an unusual height, and where, as in the Hawke's Bay District, a wide extent of level country intervened between the hills and the sea the same thing occurred as that which happened in the valley of the Seine. Rivers left their beds and cut new channels through the plains; from Napier to Wanganui roads and railways were cut through, and bridges and culverts were swept away; stock was drowned; and farms and townships were laid under water. People said that the height of the flood was unprecedented. Possibly it was; but there is no doubt that the ununusual height was in a great measure due to the increasing extent of clearing on the high lands where the rivers have their origin.

As time goes on, phenomenal floods will occur again, and former records will be beaten: for as the hills become more denuded the floods will become proportionately more destructive. It would be wise, therefore, for the Napier people to take warning from past experience, and make more ample provision for the egress of the water from the lagoon into which several large rivers discharge themselves, as it is quite within the bounds of possibility that it may cut its way through the lower portion of the township, or perhaps carry away the harbour-works at the Spit.

(2.) *Erosion and Silting.*

Erosion and silting generally go together, and either one or the other happens according to the velocity of the current in a river-bed. When the course of a river is steep, and the soil is of a soft or friable nature, the water in the proportion of its volume and velocity scoops out the bottom, and the excavation works back until it reaches a substance of sufficient hardness to be resistant, when a waterfall or permanent rapid is formed. But as the inclination of the bed becomes less the flow of the stream is retarded, and the substance that has been brought down by the current tends to settle in the bottom. In flood-time, however, large masses of stone are swept down, and by grinding against the rocks in the sides and bottom, as well as by mutual attrition, they are rounded into pebbles, becoming smaller and smaller as they travel along, until they wear down into gravel, and eventually into fine sand, which is carried in ripples along the bottom. Meanwhile all soft rock, clays, and earthy matter are quickly resolved into mud. When the bed approximates so nearly to a level that the rate of the current is less than 6 ft. per second on the bottom, then the river is no longer able to shift the solid material, and only the impalpable particles of mud, which may be almost said to be held in solution, are carried along.

This is the process known as "silting," and it is easy to see that the quality of the silting must entirely depend on the character of the river-bed and of the nature of the material brought down.

When the bed is short and steep and the incline is continued to the coast, the bulk of the silt is carried down to the sea, and no harm is done unless the mouth of the river be situated in a harbour, when, of course, trouble may arise from the shallowing of the water.

It is when a flooded river traverses an alluvial plain that the silting does most damage. The *débris* brought down by the head-waters must find a lodgment somewhere, and, as the current loses its velocity on reaching the level country, it is no longer able to bear its burden along. The silt therefore lodges on the bottom, and the bed gradually rises until the water is forced over the banks. Then the water breaks away and cuts a new channel for itself, which in time fills up, and the same thing happens over again.

Numberless instances of this process are found in many parts of both the North and the South Islands. Wherever, as in Hawke's Bay, Canterbury, &c., the alluvial plains are backed by a mountainous country the surface is often torn away, the land is scored in every direction, and the fertile soil covered with a deposit of stones, gravel, and slime. A notable instance occurred during the great Napier flood of 1893, already mentioned, when the River Ngaruroro left its bed, and, joining with the Tutaekuri, cut its way through the road and railway to the sea.

A foolish tradition has prompted local governing bodies and private owners in many places to plant the river-banks with willow-trees, with

the view of protecting them against the scour of the current But the scheme generally defeats its own object, and is often the cause of much mischief, which, moreover, is not always confined to the locality in which the planting takes place. Sooner or later, especially if the river is a rapid one, and runs through alluvial country, the trees are undermined and swept down until they are caught by some obstruction or are stranded in some shallow place. Here they intercept the silt and the floating *débris* that comes down with every flood, and an island or dam is formed, which drives the current into the banks, or even compels it to seek a new channel. In the Lower Waikato the obstruction of the willow islands has caused the bed of the river to silt up to such an extent that in many places the level land on the banks is flooded every winter, and the Township of Mercer is frequently under water after a few days' heavy rain.

It may be asked whether the damage done by the willow-trees has anything to do with the subject of this paper, which professes to deal with the effect of the disappearance of the forest. The answer is that if the forest had not been removed the damage done by the willows would be comparatively trifling—if, indeed, it would have been considered necessary to plant them. But, as I have endeavoured to show, it is the removal of the forest that is directly responsible for the growing violence of the floods, and therefore for the increasing amount of silt and floating detritus, which the willows intercept.

There is another aspect of the silting question that must not be overlooked—viz., the formation of river-bars and the silting-up of harbours. All the mineral *débris*, stones, gravel, and mud that are carried down by a stream are immediately deposited on the bottom as soon as the current ceases to act, which it does on reaching the sea, and here it forms a bank or shoal, which is augmented by the sand or other material which the sea washes on to it. If the river falls into landlocked water the finer particles held in suspension are carried out into the stream, and drift up and down with the tide until they are precipitated wherever there is least current. In many river-mouths, estuaries, and harbours the effect of the wholesale forest-clearing is already being severely felt. Of late years, unless where temporarily scoured out by a fresh, there is less water on many of the bars, while in some of the shallower harbours—*e.g.*, those of the Thames, Coromandel, &c.—the wharves have had to be lengthened and the buoys on the shoals moved further out. One of the most fertile sources of harbour-silt, and one not generally taken notice of, is the fine dust that is formed by the action of the sun on the bare hills, and washed by the rain into the creeks. This is, doubtless, one of the principal factors of the extensive mud-flats so frequently found in landlocked waters.

(3.) *Drying-up of Streams.*

So far I have dealt only with the evils caused by water in excess; but it can also be shown that the removal of the forest involves trouble in the opposite direction—viz., in the diminution of the supply when it is most needed.

The volume of a stream is derived from two sources—the first consisting of the water that flows directly off the surface, and the second of that which comes through the ground. Both of these, of course, are originally supplied by the rain.

Though varying very much according to circumstances, the underground supply is perhaps very much greater than is generally supposed. In permeable soil, especially if the watershed be fairly level and the surface protected by bush, there is a constant percolation into the ground, and, except in the case of a very heavy rainfall, by far the greater portion of the water goes through the earth before it finds its way to the river-bed. Even in hard rocks, underground streams, starting originally in some fault or fissure, wear for themselves well-defined channels, when, after running sometimes quite considerable distances, they emerge in the form of springs about the head-waters and sides of the creeks. It is by this underground supply that the average volume of a river is maintained. But if the bush has been removed, and nothing but a hard, bare surface remains on the watershed, then the rain, as before mentioned, runs off at once; and, unless the ground be of a very porous nature, there is no water left to feed the underground supply, and the river is starved. Unfortunately, in many extensive forest-areas the land is of clay or "papa rock," both of which are almost impervious to water. Little or no percolation can take place, and practically the whole of the rain runs off as soon as it falls on the ground. The consequence is that in wet weather we have a succession of floods, and in dry weather a dwindling streamlet, or even an empty watercourse. On a small scale this sequence of cause and effect may be seen in the dry creeks that bring such trouble to the grazier and the dairy-farmer; while on a larger scale it may be witnessed in some of the small river-ports, where for weeks—or it may be for months—there is not sufficient water to clear the channel on the bar.

(4.) *Permanent Loss of the Bush.*

It may seem rather a superfluous statement to make, that one of the results of the removal of the forest is the loss of the bush. But it is well, perhaps, to consider, before it is too late, how much the statement involves. The European and American forestry regulations, so often quoted, which provide for the judicious thinning-out and the gradual removal of the full-grown trees, and so on, cannot be made to apply to the forest of this country. No single tree once removed from the New Zealand bush can ever be replaced, while to attempt to "thin out" the New Zealand bush is to condemn it to immediate destruction. From a scenic point of view the loss also is incalculable. The New Zealand bush has grown up under conditions which, once removed, can never be restored. Favoured by special climatic conditions, undisturbed by the presence of any ruminating animal, the bush, with its patriarchal trees, its wealth of underwood, its profusion and variety of epiphytes and climbing plants, has attained a richness and beauty probably unequalled, and certainly not surpassed, in any part of the world. In a block of kauri in the Auckland Museum, measuring 8 ft. in diameter, the Curator, Mr. Cheeseman, counted no less than 455 concentric rings, each ring representing a year's growth. But the tree from which the block was cut was only a sapling compared with the giants of 10 ft., 12 ft., or 14 ft. which have been sacrificed for milling-timber. Thousands of years must have been required for their growth. How many thousands more it must have taken to evolve the conditions necessary for their existence it would be vain to attempt to guess. With a fair amount of care a specimen tree may be grown away from its natural surroundings. A kauri, a rimu, or a totara will make a very handsome object

in a park or garden. A selection of ferns and orchidaceous plants can be nursed up under artificial shelter, but who can restore what is at once the park, the garden, and the conservatory? Untold ages have been required to produce it; and once it has gone it has gone for ever. We may make fair imitations of an English forest or an English coppice. With our genial climate we may introduce variety by means of subtropical plants: but by no combination of elements, however beautiful in themselves, can we ever hope to reproduce the peculiar charm of the New Zealand bush.

EXTENT OF DAMAGE.

In the foregoing pages I have given a few typical instances of the damage that has already resulted on the removal of the forest. The facts I have adduced have either come under my own observation or are those of whose authenticity there can be no question. But the damage is going on all the time, and over the whole of the Dominion; and, as every year there is a wider area of cleared land for the elements to work on, it must every year be more widely spread. The climatic changes, the growing intensity of the winds, and the more marked extremes of temperature, might pass unnoticed, or might be accounted for by some imaginary meteorological disturbance; but no one who travels a few miles outside of our cities can be blind to the changes that are taking place on the surface of the country. In the papa land to the south-west of the Main Trunk line, and extending to Taranaki and Wanganui, very serious damage from landslips is everywhere following the advance of settlement. The same thing is occurring to an alarming extent in the soft limestone country along the east coast to the north of Gisborne; while in the mountainous district inland of the East Cape every hillside is scored with landslips, some of which are hundreds of feet high and many acres in extent. The same thing is taking place in the old kauri-workings on the Coromandel Peninsula, and in many other places too numerous to mention. Everywhere from Mangonui to the Bluff, more or less, according to the nature of the country, the land is slipping away, the surface is being eroded, and the rivers silting up at a rate and on a scale that no one would have believed possible a few years ago.

THE FUTURE.

Looking forward to the future, one is tempted to ask whether there is any prospect that the evil will ever be checked. Reafforesting and the protection of river-banks are, of course, the two remedies that are most needed. The former is being undertaken to a certain extent by the Government; but the area on which it is possible to operate is quite insignificant compared to the extent of land that is suffering; while, in regard to the protection of river-banks, it is an art that is not yet understood in this country, and one which, moreover, would be far too costly to undertake on any general scale, though a good deal might be done in special cases, such as that of the Ohinemuri River and the Lower Waihou. Speaking broadly, the trouble must go on and increase in the open country. There is no finality about a landslip, and for many years to come the rivers will wander at will over the alluvial plains, while erosion and silting will go on as before. Neither is there any hope that the residue of the standing forest will remain intact. Land must be provided for settlement, and so long as there is a demand for timber the trees will be cut down; and once the timber-trees have been removed the rest of the bush, as already shown,

will quickly disappear. In a very few years the kauri and the totara will be exhausted, and the rimu and the kahikatea, the black-birch, and the matai will not last for ever. At the present moment, owing to the rising price of timber, trees that a few years ago would have been considered inaccessible are being brought to market, while bushes that would have been looked upon as worthless in the past are now being worked for anything that will cut up into a plank or a piece of scantling. All this tends to the more rapid denundation of the country, followed by the climatic and topographical changes already described; and, as in America, in the Scandinavian Peninsula, and elsewhere, as the pulp industry follows the sawmill, once the larger timber has become exhausted, so doubtless it will be before long in New Zealand, and then the deforestation, with all its disastrous consequences, will become more rapid and complete.

It is satisfactory to notice that there is a dawning improvement in public opinion on this matter. Several well-timed articles have lately appeared in the newspapers of the Dominion, amongst which was a most thoughtful and logical exposition of the subject in a series of papers by Mr. J. P. Grossman in the *New Zealand Graphic*, since reprinted under the title of "The Evils of Deforestation." The Government also seems to be waking up to a sense of the importance of conserving some of the remnant of the forest before it is too late. And quite recently the Under-Secretary for Lands, Mr. W. C. Kensington, in reply to a criticism of the policy of the Department in withholding from settlement certain lands on the Wanganui watershed, very wisely pointed out that, unless the forest in that locality were rigidly protected, the famous "New Zealand Rhine," not only as a beauty-spot but as a navigable river, would soon be a thing of the past. While all this is very satisfactory, it must be remembered, as I pointed out in a former paper, that reservation must be more than reservation on the map. To be of any practical use reservation must be made with a barbed-wire fence, as, if cattle and pigs are allowed to enter, the fire will follow sooner or later, and the end will begin. The folly of neglecting this simple expedient has been amply exemplified in the Taranaki Mountain reserve, the Waitakerei Ranges, and in the Waipoua Kauri Forest, where much of the bush has been destroyed.

But while we have a right to demand from the Government such a protection of the public interest as is involved in the conservation of such portions of the existing forest as may be consistent with the interests of settlement, as well as in the reafforestation of the open land when such a measure may be practical and desirable, a great deal of good might be effected by private enterprise. In the neighbourhood of Melbourne it has been noticed that the hot winds and dust-storms, that are such a disagreeable feature of the Victorian climate, have lost much of their fierceness since the suburbs have been planted; while in the Waikato all old settlers are agreed that since the plantations of *Pinus insignis*, poplars, &c., which are so conspicuous in that district, have grown up the frosts have of late years not been nearly so severe as they were.

If legislation is to be invoked in this matter it might be well to consider the advisability of making it compulsory, in certain areas, for every landowner to plant and keep under timber a certain percentage of his holding. Such a measure would not only be of incalculable benefit to the country at large, but would be of very material advantage to the settler himself, as experiment has already proved that there is no more paying crop than a plantation of timber-trees.

In endeavouring to demonstrate the effect of the wholesale destruction of the New Zealand bush on the climate and on the topography of the country, and to show that these effects are far more productive of evil than of good, I do not pretend to have started any new or original theory. The science of forestry, the influence of standing timber on climate, and the action of running water are perfectly well understood in many parts of the world. In France, Germany, Austria, Switzerland, Sweden, and Norway, and many other European countries, stringent regulations on the subject are in operation, and have long since justified the wisdom of their enactment. Even in the United States of America it is coming home to the people that the "forest primeval" is neither boundless nor inexhaustible. Congress has already wisely provided for the setting-aside out of the public domain some 70,000 square miles of valuable forest land, with the view of protecting the streams and perpetuating the timber-supply in the western States and Territories; while at the present moment a scheme is under consideration for acquiring by purchase the whole of the Southern Appalachian Mountains, a district containing no less than 12,000 square miles, or over 7,000,000 acres, in one block, for a forest reserve. It would be well if we in New Zealand were to follow the example of other countries. But so long as we see the stream of logs coming down the railway or coming up the harbour, so long as the distant hills appear to be clothed with bush, and so long as our timber companies are paying a good dividend it is probable that no very earnest or systematic action will be undertaken. We fail to notice that the logs are getting smaller and smaller all the time, and we do not perceive the gaps in the sky-line of the hills, a sure indication that the bush is already far on its way to destruction.

It is my earnest hope that by a plain statement of the case, based on the experience and observation of over forty years, spent more or less in the bush, public attention may be aroused to a sense of our loss before the loss has become altogether irretrievable.

In concluding, I should like to record my grateful thanks to Mr. James Nicholson, of Waihi, for much valuable information on some of the subjects treated.

Art. XLII.—*The Platinum Gravels of Orepuki.*

By R. A. Farquharson, M.Sc.

[*Read before the Otago Institute, 2nd August, 1910.*]

With the advent upon the world's arena of modern electrical apparatus, accurate methods of chemical analysis, and improved methods of sulphuric-acid manufacture, the demand for platinum, both pure and alloyed, has gone up by leaps and bounds; so much so, indeed, that the supply is falling short of the demand. When we consider this, and also the fact that at the present time one country itself—Russia—supplies over 90 per cent. of the world's annual consumption of the metal, it is at once evident that prices must rapidly increase, and platinum become an article of great commercial value. It has seemed advisable, therefore, not so much from a scientific as from an economic point of view, to investigate the occurrence of the metal in New Zealand. In this investigation attention will, on account of the magnitude of the task, be necessarily limited almost entirely to Otago, though an account will be given as complete as possible of its occurrence in other parts of the Dominion.

As far, then, as recorded observations go, platinum in New Zealand may, generally speaking, be said to occur as follows: (1) In Auckland Province, in two places; (2) in Nelson Province; (3) in Stewart Island; and (4) in Otago, in two places.

In Auckland the more notable of the two occurrences may be described as follows: In 1882, while a shaft in one of the mines of the Thames Goldfield was being deepened from the 540 ft. to the 600 ft. level, a quartz vein was cut which was found to descend nearly vertically. It was also observed that the vein was impregnated with massive pyrites, and, since it is a matter of common knowledge that gold frequently occurs in such sulphide ores, samples of the material were taken and assayed. In the first assay, 200 grains of the crushed and powdered rock were taken, and these yielded bullion to the extent of 0·021 grain. On parting the bullion in nitric acid, it was found to still retain its silvery lustre and appearance, showing that some other metal than gold was present. Several other assays of the stone were then made, from which varying values were obtained, the highest being 0·776 grain from 400 grains of ore. This assay, on parting, was reduced to 0·126 grain, or equal to 10 oz. to the ton. The beads obtained from this succession of assays were then put together and qualitatively analysed. The results showed the presence of silver, gold, platinum, and iridium.

In the continuation of this investigation the metal was found, by assay, in a large reef both at the 540 ft. level and the 600 ft. level, but in very much smaller proportions. Several pockets of tailings from the battery —the result of the crushing of this reef stone—were also washed, and the metal was got in the shape of minute grains accompanying the escaped gold. Viewed under the microscope, the grains were usually rounded, but, curiously enough—and, indeed, quite anomalously—many were found to take the octahedral shape, some being beautifully perfect crystals. Further investigation into this occurrence is going on at the present time, and some interesting facts will no doubt be shortly brought to light.

This occurrence, of course, has a rather important bearing on the history of platinum-deposits. As will be seen in the sequel, the vast majority of occurrences of the metal are in detrital formations, and usually all attempts to trace the metal back to its original habitat have failed. Here, however, we have an actual case, borne out both by assay and by chemical analysis, of the metal found to all appearances *in situ*, and, further, in a quartz vein. The latter point also is remarkable, for there seems to be a general consensus of opinion amongst those who have given most time to the history of the occurrences of the metal that its original habitat is an igneous rock. The rocks may vary from acidic to ultra-basic in composition, but hitherto, despite the fact that Edison in America, and Roscoe and Schorlemmer, have shown that the metal occurs in rocks and reefs more widely than is thought, the occurrence in a vein must be regarded as extraordinary, the only previous occurrences of a similar nature being those at Tilkerode, in the Hartz; at Minas Gerraes, in Brazil; at Santa Rosa, in Columbia; at Beresovsk, in Russia; and at Broken Hill, in New South Wales, though the latter is a peculiar formation, differing from the others in that it consists of the gossany outcrops of veins in a country rock of schists, gneiss, and quartzites.

Of the second occurrence in Auckland very little is known. All that can be found with reference to it is that about the year 1885 J. A. Pond reported to the Auckland Institute the fact that the metal had been found at a place called the Wade, situated about sixteen miles due north of Auckland City. The rock in the immediate vicinity of the discovery consists entirely of a very dark serpentine, probably derived from the decomposition of some basic or ultra-basic igneous rock.

We shall now pass on to the second occurrence—namely, that in Nelson Province. In the north-north-west of Nelson, just inland from Massacre or Golden Bay, there occurs a series of mountain ranges. A brief description of the country from a geological point of view is essential to the proper understanding of the deposits. The following section illustrates the series just mentioned:—

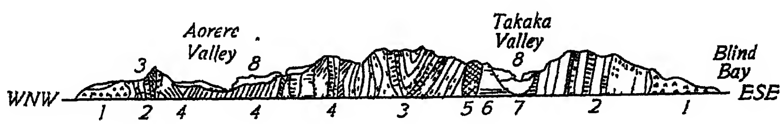


FIG. 1.

1. Granite. 2. Gneiss. 3. Mica-schist. 4. Slates. 5. Hornblende-porphyrite. 6. Serpentine. 7. Tertiary deposits. 8. Diluvium and alluvium.

Applying this section to an ordinary map of the north of Nelson, we see that the western shores of Blind Bay from Separation Point to the mouth of the Motueka River consist of granite flanked by gneiss. Proceeding from the granite, we find on the top of the Pikikirunga Range hornblende-schist intercalated with crystalline limestone. These ranges continue westwards as far as the Takaka Valley, where they are intercepted by hornblende-porphyrite and serpentine. Garnet-bearing mica-schist constitutes the highest peaks of the Anatoki Mountains, while further to the west we have clay-slates or phyllites. The Aorere Valley and the Haupiri Range belong to the clay-slate zone, and the Wakamarama Range also

consists of slates. It is the Anatoki and the Haupiri Ranges which contain the matrix of the gold and other metals found in the district.* As Hochstetter† admirably puts it, "The gradual denundation of the mountains, continued throughout countless ages, has produced masses of detritus, which were deposited on the declivities of the mountains in the shape of conglomerates, and in the river-valleys as alluvial gravel and sand. In this process of deposition, carried on under the influence of running waters, nature herself has effected a washing operation, during which the heavier particles of gold contained in the mountain detritus collected themselves at the bottom of the deposits, and close to their source, so that they can now be obtained by digging and washing."

Such, then, is a brief outline of this district. The formations (alluvial) in different parts are geologically almost exactly similar, the only difference being, of course, in the composition of the alluvium. For convenience, however, it is found advisable to divide the alluvial district into three parts—the Aorere Diggings, the Parapara Diggings, and the Takaka Diggings. Of these, the one we are most intimately concerned with is the latter, the Takaka. Its position is indicated in the foregoing section. A reference to it shows that the diggings occur on the eastern slope of the Haupiri and the Anatoki Ranges, and they comprise principally the three chief branches of the Takaka River. A section through a typical gold-bearing area appears as follows:—

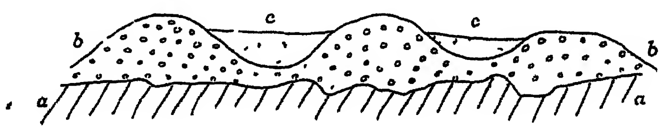


FIG. 2.

a. Clay-slate or bed-rock. *b.* Auriferous conglomerate. *c.* Alluvial sand.

The conglomerate may be cemented by a ferruginous cement, or may be quite uncemented, only loose sand lying between the boulders. The formations, therefore, do not differ at all remarkably from those ordinarily associated with gold-deposits throughout the South Island, and especially in Otago, where the formations are commonly known as the "auriferous drifts." They have, however, one outstanding peculiarity which marks them off from all other gold-deposits except those we have yet to describe, and that is the occurrence in them of osmiridium and platiniridium in small grains of a tin-white colour. These occur with the gold in conjunction with magnetite, numerous garnets, and titaniferous iron-ore (ilmenite).

It is quite remarkable that though, as has been said, these auriferous gravels are geologically similar in the district described in Nelson, and though washing has been carried on, for instance, in the Aorere Valley for a long time, yet no occurrence of platinum or its alloys has up to the present been recorded in any other area in Nelson than the Takaka. This would tend to show that there is probably some peculiarity in the Takaka surroundings that is absent from the other areas examined.

* The above section is taken from Von Hochstetter's "New Zealand," p. 102.

† Von Hochstetter, *loc. cit.*, p. 104.

A discussion of this point, with a probable explanation of the peculiarity, arrived at by comparison of this area with the platinum-bearing areas throughout the world, will be given when we come to investigate the occurrence of the metal near Orepuki, in Otago.

As far as Nelson is concerned, then, it appears that the metal is found in what, as far as the evidence goes, must be regarded as the commonest method of occurrence—viz., in placer or detrital formations.

As will be seen later on, in Russia the metal is got most abundantly from the alluvium at the base of the Ural Mountains, alluvium which has been produced exactly as the Nelson alluvium has been—*i.e.*, through denudation and the sorting-action of water. In Columbia, British Columbia, Brazil, United States, Burmah, France, New Caledonia, and Tasmania the mode of occurrence is exactly the same, so that, in all these countries, to arrive at the original matrix of the mineral we must first trace back the boulders and detritus to the parent rock.

Of a nature almost exactly similar is the occurrence of platinum in Stewart Island. Sir James Hector, in the "Transactions of the New Zealand Institute" (vol. 2, pp. 185, 371), reports that small flat grains of a steel-grey or silver-white colour have been found associated with the gold in alluvial deposits in the island. Nothing further, however, is known about this occurrence.

We come now to the occurrences in Otago, of which there are two. The less important of the two is that reported from the Gorge River, on the west coast, near the celebrated Milford Sound, in Fiordland. This locality is remarkable owing to the presence with the platinum of that peculiar nickel-iron mineral awaruite. In appearance it is not unlike platinum, and was mistaken by the miners for that metal. An analysis of it runs as follows:—

	Per Cent.
Nickel	67·63
Cobalt	0·70
Iron	31·02
Sulphur	0·22
Silica	0·42

Both the metal and the awaruite occur in a district composed almost wholly of serpentine and dunite. The awaruite has actually been found in the serpentine. From this, therefore, it would appear, as Professor J. Kemp points out, that the platinum and awaruite are excessively basic segregations in basic igneous rocks, the dunite specially being ultra-basic.

Occurrences of a similar nature, in which awaruite occurs with the platinum, are reported from California, Oregon, and British Columbia.

There still remains for consideration the second occurrence in Otago; but, as most of our investigation deals with this occurrence, it will be sufficient here to remark that platinum has been known in Otago for some seventeen or eighteen years, but to such a small extent was its value recognized, or so great was the ignorance of the miners who came into contact with it, that it was not until about eight years ago that efforts were made to collect or save it. Up to that time it had been almost contemptuously thrown away.

The first recorded occurrence was about the year 1888, when a miner searching for gold found some ounces of it at the mouth of the Waiau River. The occurrence created very little stir at the time, and the miner

even so little valued what he found that he gave most of it away. No further notice was paid to the metal till it began to be saved from the tailings in hydraulic sluicing. The locality from which most of the Otago platinum is obtained is in and around the Township of Round Hill, in Southland, almost due east of Orepuki, though it has also been obtained in small quantities, with gold, along the beach from the mouth of the Waiau to the Orepuki Beach.

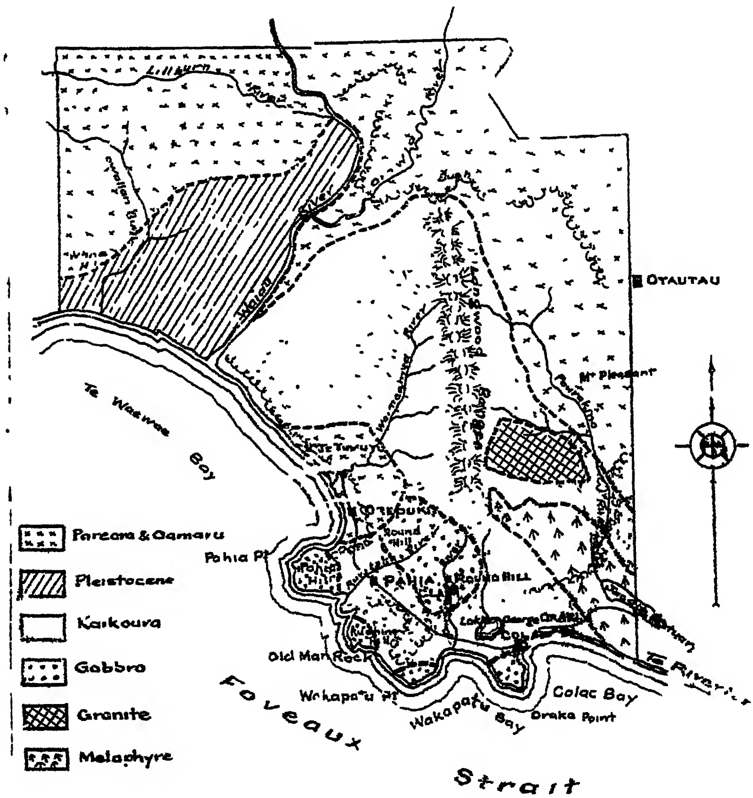


FIG. 3.—GEOLOGICAL MAP OF THE ROUND HILL GOLD AND PLATINUM DISTRICT. (Scale, eight miles to an inch.)

The above, in conjunction with the occurrence on which this paper is based, is a fairly complete account of all recorded occurrences of the metal in New Zealand up to the present time.

I shall now proceed to an investigation of the occurrence at Round Hill and Orepuki. In this investigation it is my intention to treat the subject from the point of view of (1) the physiography, (2) the geology and the petrography, of the country; and, further, to endeavour to trace the metal to its original source.

The accompanying map illustrates the district as a whole, geologically and topographically.

GENERAL GEOLOGY.

Having got a general outline of the geographical characteristics of the country, we are now in a position to devote some little attention to its general geology. As will be seen from the accompanying geological map, the geological masses we have found represented are six in number—viz., (1) Kaikoura formation, (2) Oamaru formation, (3) Pleistocene, (4) basalt, (5) granite, (6) melaphyre.

As is usually done, we shall begin with the oldest, the Kaikoura formation.

Captain Hutton, when Provincial Geologist of Otago, in 1872, gave in his paper on the geology of Otago a description, on general lines, of the structure of the west of Otago, which we think it will be highly advisable to make use of here. "The whole of the District of Southland," he says, "is included in an inclined trough of Palaeozoic and Secondary rocks, the major axis of which lies in a south-east and north-west direction, rising to the north-west where the rocks are thrown up and close the upper end of the trough. The lower end, towards the Mataura River, is open. The belt of Palaeozoic rocks that forms the rim of this trough runs from the Umbrella Mountains on the north-east, round by the Takitimu Mountains and Longwood Range on the west, and passes into the Bluff Hill on the south-west. In its folds are enclosed large masses of Secondary rocks The south-west edge of this trough has been broken down in several places, and Tertiary rocks have been deposited indifferently on both the inside and the outside and overlapping its edge. These have in their turn been largely removed by denudation, and replaced by immense deposits of gravel and silt."

From this it will be seen that a section across the major axis of the trough taken in the district with which we are at present concerned may, as it actually does, appear as follows:—

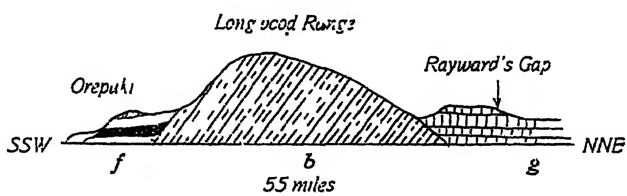


FIG. 4.

At f and g we have the trough, inside at f and outside at g. b. Slates. g and f. Tertiary rocks.

The Kaikoura formation of Hutton is a part of the Upper Palaeozoic period, and is also a part of the Te Anau series of Hector, classed in the Upper Palaeozoic also. It is represented in the district by the Longwood Range and its outskirts (see map). Roughly speaking, then, it comprises all that part of Southland extending from near the eastern bank of the Waiau to near the Pourakino River, and from the head of the range to the sea-coast.

The rocks consist principally of clay-slates and grey sandstones or quartzites. According to Sir James Hector, who reported on the district in 1864, and whose paper appeared in the "Quarterly Journal of the Geological Society" in 1864, these rocks consist of indurated shales with calcareous sandstones: but an examination of them leads us rather to support

Captain Hutton. The quartzites are grey in colour, and consist of rolled quartz grains of fair size, with only very subordinate feldspar, united by a clear cement, which is of the nature of a crystalline outgrowth from the grains. Moreover, the indurated shales of Hector are probably little more than the clay-slates of Hutton. The general strike of the beds is south-east and north-west. No fossils have been found.

Associated with these rocks are rather numerous intrusions of igneous rocks. These have been recorded by several observers. Hutton, in the paper above referred to, says that associated with the Kaikoura sandstones are dykes of diorite. Hector, in his geological map of Otago (in 1864), has diorite rocks shown at such places as Oraka Point, Pahia Hill, and Wakapatu Point. Further, in the *New Zealand Mines Record*, vol. 3, appears the statement that the Longwood and Takitimu Mountains consist partly of a massive development of diorite and syenite in mountain masses and in strong intrusions among sedimentary formations.

An examination of the district confirms these statements to a certain extent. Three distinct types of rock have been identified by me. These occur as giant intrusions, for the term "dyke," usually associated with minor intrusions, very incompletely describes these. The outcrops of diorite at Oraka Point, Pahia Point, and Wakapatu Point, mentioned by Hector, but not mentioned by Hutton, were confirmed; and, further, another distinct outcrop was noticed on the edge of the beach near Orepuki Township. Further, the whole district extending from Orepuki inwards and from Round Hill along the base of the Longwood as far as Colac Bay was also found to consist of this same rock. Whether the outcrops at the points before mentioned are just branches of this one great intrusion or not, it is hard to say, for the outcrops cannot be followed up on account of the bush; but it seems extremely likely.

As this diorite rock forms the whole rock-mass of the Round Hill district, we shall defer any further consideration of it till we come to describe the minute geology of the Round Hill Claim.

In addition to the diorite outcrop, two intrusions have been observed by us. It is a remarkable fact also in this connection, that, though both Sir James Hector and Captain Hutton have separately examined the country under review, neither of them has observed either of the two intrusions mentioned below.

A reference to the map will show that both outcrops occur on the eastern flank of the Longwood Range, and consist of (*a*) melaphyre and (*b*) granite. It is to be noted, however, that Hutton in several places speaks of rocks which he calls "argillites." Also, these he says occur in the Kaikoura formation in various places, and he defines the term "argillite" as a name given to a rock formed from thick beds of clay that have undergone a sufficient amount of metamorphism to obliterate the lamination, while it has not been sufficient to induce any signs of foliation.

Further, argillite, he says, is much jointed in several directions so as to break into irregular rhombohedra. Now, this melaphyre is a rock bluish-green in colour, and with none of the appearance usually associated with igneous rocks; no minerals can be identified in hand-specimens, and no cleavage-surfaces are anywhere evident. Also, a rough jointing is sometimes seen in it, probably a relic from the days when it was an undecomposed basalt. It is just possible, therefore, that what Hutton calls an argillite may be here, at any rate, a melaphyre. Whatever may be the

case, however, no mention heretofore has been made of a granite. We shall therefore describe each in detail.

The melaphyre has the appearance in hand-specimens above outlined. It occurs very prominently round the coast towards Colac Bay from Riverton, and extends back into the Longwood Range for some distance, until it appears to thin or pinch out, as in the map. The actual boundaries of the mass, or the junction of it with the main rock of the range, have not been made out with any accuracy, owing to the great difficulty of following the rock through the interminable bush. From what could be gathered from miners, however, as well as from a consideration of the rough direction at Riverton, it is thought that the position in the map is fairly accurate.

The rock is very tough, and splinters with more than usual difficulty, much like some close-grained phonolites. It does not seem to be acted on by denuding agencies with any great rapidity, and is fairly hard.

In section, the most noticeable feature on looking at the slide is the large amount of decomposed material. In this decomposition not only is it the feldspars that take part, but the olivine too is almost all serpentinized. The minerals seen in the section are—

Plagioclase.—This forms several phenocrysts in the section examined, and, judging from the extinction-angle on—*i.e.*, at right angles to—the brachypinacoid, which varies between 25° and 30°, the mineral is mostly a basic variety of labradorite gradually passing into bytownite. The crystals show the albite lamellar twinning very well, for some of the phenocrysts are not so decomposed as others. Combined with the albite the pericline and Karlsbad twinning occurs, but rather rarely. Besides the phenocrysts is an abundance of very fine lath-shaped feldspars forming a great portion of the groundmass. These are all semi-decomposed, forming, like the phenocrysts themselves, patches of calcite.

Olivine.—Very few patches of this mineral have been identified with certainty. Its place is almost always taken by yellowish-green masses of serpentine and other products due to the weathering of the mineral. In those which have been identified the mineral is quite without crystal outline, exhibits the usual cracks, and is usually surrounded with the serpentine border due to decomposition. The form appears to have been rounded, or in some cases oval, and the mineral is usually quite colourless. Here and there occur patches of what appears to have been olivine, but nothing now is left except a mass of material like calcite, showing peculiar radial extinction.

Augite.—This is remarkable as being the only essential mineral which has resisted the weathering-agents. In hardly a single case does the augite—at any rate, in phenocrysts—appear at all decomposed. It occurs in roughly rectangular forms, is usually pale in colour, and here and there shows a lamellar twinning. The forms represented are the orthopinacoid, the base, and rarely a dome. The extinction-angle is high, being usually over 30° in the prismatic zone. Where decomposition has set in the products are mostly chlorite, yellowish-green in colour. The mineral occurs as it does in most basalts, in two generations. The groundmass appears to have been studded with small grains of the mineral having the characters of the phenocrysts, but in a more advanced stage of decay.

Besides these essential minerals there occur small grains of magnetite and rather numerous crystals of apatite in long acicular crystals. Their further characters cannot, however, be made out.

With regard to its structure, the rock belongs to the holocrystalline class of basalts, for, while there is a fair amount of isotropic material present, this is due to alteration and not to the presence of glassy matter. Further, the order of crystallization of the various constituents is not well marked, the mutual relations between the augite and feldspar with regard to priority varying considerably. No ophitic structure has been observed.

Turning now to the *granite*, we see that, in hand-specimens, it is of a white colour, rather fine-grained, with pronounced orthoclase differing very little from white in colour, and pronounced quartz crystals. The ferro-magnesian mineral is biotite, but is unusually rare in occurrence; the rock, therefore, resembles in appearance some specimens of ditroite without the blue colour of the sodalite.

In section, the rock is seen to be made up mainly of quartz, orthoclase, and biotite. The *quartz* occurs in large plates without crystal outline, enclosing in some cases fluid pores, which are arranged in lines. Occasionally the quartz occurs fixed into the interstices between feldspar crystals, showing probably that the mineral crystallized after the feldspar.

The *orthoclase* also occurs in large plates, but, unlike the quartz, is usually semi-decomposed to form kaolin. Karlsbad twinning is usually to be seen. In addition to the orthoclase, several crystals of microcline and oligoclase are to be seen. The microcline shows the peculiar cross-hatched appearance under crossed nicols, and the oligoclase, of which a considerable amount occurs in the rock, shows both Karlsbad and albite twinning lamellation. A very well-marked zonary banding has also been noticed in the orthoclase.

The *biotite* occurs in small plates with ragged outlines and no distinct terminations. It exhibits strong pleochroism from light yellow to deep brown, and has almost straight extinction, and is very susceptible of alteration. The latter produces a green coloration, and in places a green chloritic pseudomorph with pieces of magnetite. Its inclusions are rare, and consist mainly of magnetite and pieces of apatite. No accessory minerals have been seen.

The structure is that characteristic of all plutonic rocks—*i.e.*, hypidiomorphic—only a minor proportion of the constituents developing their external forms freely. The normal order of the crystallization has also been obeyed: the biotite and magnetite have first crystallized, then the feldspar, and lastly the quartz with microcline, though the oligoclase has probably preceded the quartz.

The next geological formation we must discuss belongs to the Miocene period in New Zealand, and, more particularly, to the series called by Captain Hutton the Oamaru and Pareora series. The strata belonging to this series Hutton, in the report on this district above referred to, has seen fit to subdivide as follows: (*a*) Brown-coal formation; (*b*) Oamaru formation proper. We shall deal with these separately.

(*a.*) *Brown-coal Formation.*—The main body of this occurs skirting round the Wairaki Hills, but another small patch is also found on the south-west side of the Longwood Range at Orepuki, and for a short distance on both sides of the Waimeamea River. As Hutton remarks, it never rises to great altitudes, but occupies portions of old valleys scooped out of Secondary and Palaeozoic rocks. The Orepuki occurrence has roughly the shape of a triangle, with an area of about one and a half square miles. The seam is exposed only in water-races, in which some difficulty was experienced in

measuring the thickness. According to some of the miners who have worked on the races, the thickness is about 15 ft. The formation is at a height of 200 ft. above sea-level, covered by dark, tough shales, with a floor of brownish-coloured shales, and with a covering of soft green sandstone. These shales contain leaves of dicotyledonous plants, which have not yet been identified with any degree of certainty. As the formation nears the beach the coal has been washed away, and its place has been taken by a thick deposit of sands and gravels of Pleistocene age. Associated with these Pleistocene gravels are also beds of lignite, some of which can be distinctly seen on the sea-cliffs. This lignite is muddy and very poor, and has nothing whatever to do with the brown-coal formation. A section through this Orepuki occurrence appears as follows :—

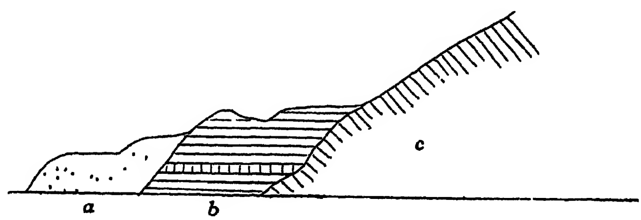


FIG. 5.

a. Soft sandstone, with lignite. *b.* Brown-coal formation (Oamaru). *c.* Slates (Kaikoura).

(*b.*) *Oamaru Formation.*—A reference to the map shows that in the district this formation has a comparatively large development. Leaving out of account the Orepuki portion, we may describe it thus: Beginning in the south west corner, to the north of the Pleistocene deposits, it stretches to the northern boundary; then away to the east; crosses the Waiau River about the neighbourhood of Clifden, whence a narrowing tongue extends nearly to the mouth of the river; extends to the eastern boundary after skirting the outlying northern spurs of the Longwood Range; and finally pinches out just above the Jacob's Estuary, on the border of which Riverton is built. The basaltic formation of Mount Pleasant stands surrounded by it.

Viewed on a large scale, the strata seem to be nearly horizontal, but rising slightly to the north. The rocks are almost wholly composed of shelly limestone or calcareous sandstones. The limestone is in places very fossiliferous. The following fossils have with certainty been recognized: *Hemipatagus formosus*, *Waldheimia lenticularis*, *Terebratula gualteri*, *Pecten hochstetteri*, *Pecten polymorphoides*. Others have been found, but their identification is not yet complete. It will be seen that several of these fossils are identical with those found in the limestone formation of Oamaru, in Otago, and at the Weka Pass, in Canterbury. These fossils characterize the oldest Tertiary and marine beds in New Zealand.

The limestone, which at places forms cliffs 30 ft. high on the banks of the Waiau, is not pure, averaging usually between 60 and 70 per cent. of CaO.

Sir James Hector, in a map of this district prepared in 1864, considers this formation as belonging to the Pliocene period, and describes it as a Pliocene marine tertiary. Undoubtedly it is marine, but the occurrence of the fossils just mentioned would assign it rather to the Miocene than to the Pliocene.

Finally we shall consider the Pleistocene deposits. These are almost entirely gravel deposits, the only exception being the fairly large formation occurring to the west of the Waiau River and bordering Te Waewae Bay. The formations are composed of beds of sand, clay, and shingle, with occasional seams of lignite in the lower portions. These lignites are usually poor; occasionally well-preserved trunks of trees are found in them, and a well-marked vegetable structure is often seen; sometimes they contain resin, like the coal in places at Nightcaps.

The low land on the west of the Waiau is also composed largely of gravel, and consists of a fairly flat plain, interrupted here and there by small hillocks, which give to it an appearance very like that presented by a peneplain. The valley of the Waiau River, too, in its upper portion is said to be strewn with fragments of gneiss and greenstone, along with other eruptive rocks.

The gravels all along the coast from the Waiau to Jacob's Estuary are all referable to this period. They are usually, however, covered over by silt and surface soil. Their origin is probably due to the spreading-out by the sea of the detritus brought down by the rivers.

Such, then, is the general geology of this district. The following sections, together with the one previously given showing the relation of the Longwood to the geological structure of the south-west of Otago, will serve to illustrate the main features just outlined:—

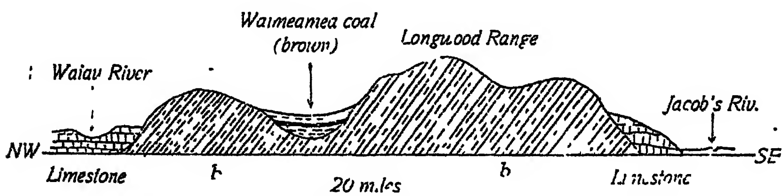


Fig. 6.—Section from Jacob's Estuary to the Waiau River.

b. Palaeozoic slates, &c.

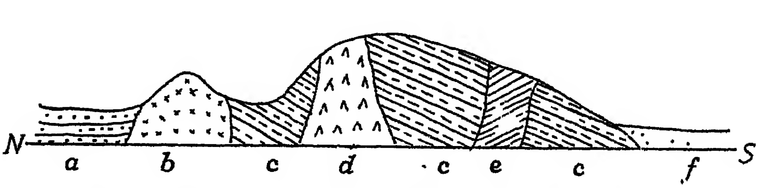


Fig. 7.—From North of Mount Pleasant to the Sea-coast.

a. Oamaru formation. b. Basalt. c. Palaeozoic slates. d. Granite. e. Melaphyre. f. Gravel plain.

It will be interesting, before concluding, to compare the district with that of the Coromandel Peninsula, in Auckland. One cannot but be struck with the similarity on broad lines between the two. We have seen that the Longwood district consists of a main central ridge running north and south, with spurs given off on all sides, and the whole densely wooded. The main axis, or what might be called the base, consists of Palaeozoic slates. These are pierced, as we have seen, by dykes consisting of diorite, melaphyre, and granite. On each side of the axis come younger rocks of Tertiary age.

Look now at the Coromandel district. It also consists mainly of a mountain-ridge running nearly north and south, with numerous spurs, and all densely wooded. The base or bottom of the structure consists of Palaeozoic slates, which are also pierced by dykes. The latter are composed of trachyte, and what was originally called by Captain Hutton a diorite, and what has since proved to be in some cases a dolerite and in others a melaphyre. Further, the older formation forms the centre, and younger formations of Tertiary age form the outskirts. Brown coal also occurs in the peninsula in places, resting unconformably, as in the Longwood, on the older slates.

In addition, it may be remarked that quartz veins occur in the Coromandel, and they also occur on the south-eastern slopes of the Longwood. Gold, too, is found in both localities.

A similarity is also to be noticed with the structure of Great Barrier Island, north of Cape Colville Peninsula. This, as Captain Hutton points out (New Zealand Geology Reports, 1868), consists of a base of dark-blue siliceous slates, penetrated here and there by dykes of quartz-porphyry and what he calls a diorite, but which may be of similar character to the diorite of the Coromandel dykes—*i.e.*, either dolerite or melaphyre.

There is, however, a marked difference in the associated volcanic rocks in the two districts. In the Longwood district the only volcanic rock is the basalt already described, but in the Coromandel district hypersthene-andesites were first erupted, and these were followed by large outpourings of rhyolites characterized by the presence of tridymite. The andesites are everywhere older than the rhyolites.

Round Hill District and Claim.

General Appearance.

It will be seen that the country to the north consists of Round Hill and two chief ridges. Round Hill has a barometric height of 1,120 ft., and the ridges of approximately 700 ft. and 800 ft. respectively. Between the Hill and the first ridge there is a gully, down which the Rurikaka Stream flows. Between the first ridge and the second occurs a steep-sided gully, down which flows in a rapid stream the main branch of the Ourawera River. Between the second and the third ridge occurs another similar gully, down which the other branch flows. A rather similar succession goes on all round the lower spurs of the Longwood Range.

In a southerly direction from the Rurikaka a rather peculiar knob is found, bordered on the far side from Round Hill by the Ouki Stream, the bed of which is flatter than that of the other streams above it. From this stream, both on the east and on the west side of the district, a more or less gradually rising slope occurs, extending on the west towards Pahia and on the east towards Riverton.

It will thus be seen that the Ourawera River flows in a kind of obtuse V-shaped hollow, rising rather abruptly to the north, and sloping gradually from the base of the ridges to the sea. On each side the land rises fairly rapidly, but more so on the east than on the west, and the slope increases as we go towards either the north-west or north-east. Thus the greatest height of the land on the west side (with the exception of the knob previously mentioned) is about 500 ft., while on the east side it may rise to 700 ft.

The Township of Round Hill is between 250 ft. and 300 ft. above sea-level, the claim itself, occurring as it does along the eastern bank of the river, being about 200 ft. to 230 ft. above sea-level.

From the bottom end of the claim the land is almost quite flat on all sides, and it is on this flat plain at the base of the spurs that Lake George is situated.

The whole district is densely wooded; even Round Hill, though a trig. station, is covered with trees of unusual height. In the course of our investigation, realizing the importance of Round Hill as an observatory, we made an excursion to the top.

The Ourawera, we could see, has now reached its base-level of corrosion in that portion which extends from the base of the ridges to the coast. Its action now is one of erosion—*i.e.*, that gradual eating-away of its banks to form ultimately a more or less flat plain. The deposits, therefore, now being formed from the river are those got from the denundation of the rocks and soil in the neighbourhood.

The bank on the west side is gradually sloping at once from the bed of the river, but on the east side there is a rather steep cliff from the bed, about 20 ft. to 30 ft. high, and extending almost the whole length of the claim. This has been formed probably from the sluicing which has been going on for a considerable number of years.

Of the coast-line, all that need be said is that it has characters exactly similar to the bed of the river from the east side. The land ends in a cliff of about 10 ft. to 30 ft. high, and is flat from there inland. The beach is very flat.

General Physiography of the Neighbourhood of Orepuki.

If we look at a detail map of the Province of Otago, and especially of the southern portion of it, we cannot but be struck with the almost uninterrupted growth of bush which prevails as we go westwards from Invercargill to Orepuki. Almost from Invercargill itself to the water's edge on the west coast there extends a continuous stretch of forest of the very densest description. Not only does this occur near the coast, but for miles and miles inland until the Waiau River is reached, and if a clearing is met one finds it due only to the indefatigable labours of some prospectors on the look-out for gold.

It is at once seen, therefore, that any examination of such a district is fraught with more than ordinary difficulty. Even at the present time, in spite of the fact that the railway-line to Te Tumutu has been open for more than twenty years, in spite of the fact that there is still a large inducement in the Dominion for the extension of the sawmilling industry, and in spite of the fact that the district has proved to be more than ordinarily auriferous, the means of locomotion are restricted to bridle-tracks, bush-tracks, water-races, and sawmill tram-lines. Decent roads are quite unknown in the district until we get as far north almost as Nightcaps. One cannot wonder, then, that the information in regard to this district is very meagre; nor can one wonder that what information there is, geological or otherwise, is more or less of a contradictory character Even in my own case, though I had the advantage of tracks, water-races, and tram-lines not to speak of a guide or two possessing a fair knowledge of the country, my path was far from easy. When I consider, therefore, that Dr. Hector and Captain Hutton made a survey of the country, the former in 1864 and

the latter only a little later, I can easily see how very difficult it must then have been for them.

While the above remarks are applicable to the whole of the western and south-western part of the Southland County (except, of course, the alluvial plains of the Waiau), they are especially applicable to the district which we have under investigation. This is bounded on the west side by the meridian of 167° 30′, on the south by Foveaux Strait and Te Waewae Bay, on the east by the meridian of 168°, and on the north by the parallel of latitude 45°.

The physiographical features can be classified conveniently as follows: (1) The mountains, (2) the plains, (3) a lake, and (4) the rivers.

The mountains of the district are represented by (*a*) the Longwood Range and its offshoots, and (*b*) various isolated peaks.

The Longwood Range consists of the main ridge running almost due north and south, and tapering at the northern extremity to a single peak called Bald Hill. The average height of the ridge is about 3,000 ft., and its breadth at the widest part is about four miles. From both sides of the range extend about five or six parallel spurs, which slope gradually down to the plains at the bottom. At the lower extremity of the range there are also several diverging spurs, and to the most westerly of these the name of Round Hill has been given. The whole range, including the spurs and the valleys, is very densely wooded, and, except for some water-races and a sawmill track or two, is practically virgin forest, with trees on an average about 50 ft. high. In contradistinction to most of the ranges of Otago, the mountains of this one are not rugged. Their summits are rounded, and they altogether present an appearance more like hummocks than mountain-peaks.

It is hardly necessary to state that the range constitutes the chief watershed of the district, the main river-system having its origin entirely in the valleys which everywhere occur on the flanks of the ridge.

Various isolated peaks occur on the extreme north-west of the district, but these do not attain any size, the highest being only about 1,000 ft. high, and composed entirely of a Pleistocene gravel formation.

Other isolated peaks occur, jutting out into the sea south of Orepuki and along the coast as far as Riverton. They also nowhere attain any considerable size, and are always completely covered with bush; but they give the country a rather peculiar appearance, and, in conjunction with the plains which are always associated with them, they are strongly suggestive of the idea that the district has been submerged comparatively recently. More will, however, be said with regard to this later on.

Let us now turn to the plains. Generally speaking, the whole district between the Longwood Range and the sea-coast all around consists of one densely wooded plain. In fact, it is quite remarkable that the whole of the south-east coast of Otago from the mouth of the Mataura River to ten miles west of Waiau, Preservation Inlet, on the south-west coast, is extremely flat; nor does it begin to rise until a distance of more than thirty miles from the coast is reached (the only exception to this being in the case of the district between the Longwood and the coast, where the range is distant only about five or six miles from the sea-beach). Further, too, a consideration of the soundings round this part of the coast shows that the slope continues gradual for some considerable distance under the sea-level. This plain consists, as far as can be made out, of a gravel formation, the pebbles being such as would be brought down by the river—*i.e.*, more or

less rounded, smooth, and only in rather rare cases flat. This plain looks therefore, much like one of fluviatile deposition, such as occurs in Otago, in the Waikato district of Auckland, and, according to some authorities, in Canterbury. Further evidence and opinions as to its origin will appear later on.

A continuation of this plain is found east of the Longwood, intersected here and there by streams flowing from the range. The most pronounced in character, however, of all the plains is that formed by the Waiau River. This river during nearly all the latter half of its course flows between banks composed partly of pebbles and partly of limestone or calcareous sandstone. For a distance of two miles in some places, in others three, on either side of the river flat alluvial land extends, passing gradually into a series of hilly spurs, and from there to the mountains. It is this flat that constitutes the Waiau Plain. It is very wide at the mouth (about a mile), and gradually tapers backwards, but it extends for many miles up the river, and south of Lake Manapouri the land is so flat that marshes have been formed. Evidently it is a plain of fluviatile deposition, the uniformity of surface being produced by the deposition of gravel and silt as the fall of the river has diminished. Pronounced terraces have been seen in places on the banks, and, since the flow of water is so great that these could hardly have been formed by changes in the course of the river, it is legitimate to assume they are due to a small elevation of the surrounding district, especially as the depth of the river is very considerable.

No other plains worthy of mention occur.

The rivers must now be considered. These are: (*a.*) The Pourakino, which rises amongst the easterly spurs of the Longwood, flows generally in a southerly direction, and after a rather tortuous course empties itself into Jacob's Estuary near Riverton. It is chiefly interesting on account of the gold-washing that goes on near its source and as far as the point where the river enters the plains. (*b.*) The Ourawera, which, rising in the southerly spurs of the Longwood, flows due south, and, with a tributary from Lake George, enters Wakapatu Bay. It is along the course of this river that the gold and platinum grains are found which form the basis of this paper. (*c.*) The Rurikaka River, which has its source near the base of Round Hill, and, flowing in a south-westerly direction close past Pahia Township, enters Foveaux Strait. (*d.*) The Waimeamea, which, having its source on the western slopes of the range, with a tributary system very like that of the Pourakino, flows in a south-westerly direction across the plain, and after a remarkably tortuous course across the flat country enters Te Waewae Bay. (*e.*) The Orawia, a tributary of the Waiau, may also be taken as a separate stream. It takes its rise in the comparatively hilly country to the north of our northern boundary, flows also towards the south-west, and after a tortuous course joins the Waiau opposite Bald Hill.

In the case of the last three rivers—viz., the Rurikaka, the Waimeamea, and the Orawia—and to some extent the Waiau, which we shall describe next, it will be noticed that they fall very conveniently into the classification (adopted by Professor J. C. Russell in his "River Development") of streams which have their source in mountain-ranges and flow across broad plains to the sea. Such streams may be divided, he says, into three divisions—the mountain tract, where the streams flow impetuously in narrow depressions; the valley tract, where the stream widens and is bordered by flood-plains; and the plains tract, where the grade is still

more gentle, and the stream meanders in broad curves through alluvial lands of its own manufacture.

With the three streams above we have the mountain tract pronounced, followed by a more or less pronounced valley tract. The plains tract is very evident, being shown by the complicated meanders of their courses. A similar course is followed by some rivers in the North Island, especially the Wanganui. This river, coming from the plateau of the centre of the mainland, flows in its lower portion through flat plains which quite recently (in the Pliocene) were beneath the sea-level. Complicated meanders are thus produced, and in this case, as in others, lakes are in process of forming by the erosive action of the waters on the banks. This action is especially to be seen in the case of the Orawia and Waimeamea.

It is usually understood that rivers acquire complicated meanders in their courses comparatively late in their period of existence. The work which a river unceasingly carries on is the bringing of its bed to its base-level of corrosion, after which the slow erosion of its banks begins. But, while this is true in most cases, it is not always true. As Professor Russell points out, a similar phenomenon may be witnessed with even young rivers when the land through which they flow has recently been raised from beneath the sea, and, as will be shown afterwards, it is probable that such has been the fate of at least some of the coastal part of the district.

Finally, the Waiau River has to be considered. Easily the largest of the Southland rivers, this notable river has a discharge of about 1,130,000 cubic feet of water per minute, or two-thirds the amount of the Clutha River. Though broad and deep, it is, even when flowing across the plains, unfortunately too rapid for navigation. Unlike most rivers, it starts away as a large river from, not a hillside, but from the southern extremity of Lake Te Anau, the largest lake of the South Island of New Zealand. After rushing swiftly over eight or nine miles of large boulders between high banks it enters Manapouri Lake. From this it emerges at the south-east corner, to be joined almost at once by the Mararoa, itself a good-sized river. Some fifteen miles further on it receives the water from the Monowai Lake and the Hunter Mountains, and thenceforth, with a rather tortuous course, it flows in a southerly direction to empty its waters by several mouths into Te Waewae Bay.

In addition to these features, a lake occurs in the district midway between Wakapatu and Colac Bay. Lake George, as it is called, is only about 100 chains long and 60 broad. The depth is in no case more than 15 ft., and this fact, together with the marshy nature of the surrounding land, gives the impression that it is either a relic of a former depression or is due to depression actually in process. It is supplied by a small unnamed spring from the lowest spurs of the range.

Of the beaches which occur along the coast all that need be said is that they are unusually flat. At Orepuki the beach at low tide extends for fully 50 yards along the sand to the margin of the water.

GEOLOGY OF THE CLAIM.

It has already been remarked that the whole district extending for about two miles from Orepuki Township into the Longwood and along the base of the range about Round Hill to the edge of the coastal plain consists of a mass of diorite, possibly as an intrusion. This rock forms the base or bed-rock of the claim, and therefore calls for close attention.

An examination of the rock confirms Captain Hutton's description of it. It consists, in hand-specimens, of whitish feldspar and crystals of black or dark-green hornblende showing prismatic cleavages rather prominently. Occasionally, as is common in all igneous masses, parts of the rock are finer grained than others, and the rock then has a slightly lighter green colour. On exposure to the weather the feldspar is very soon acted upon, disappears to a great extent, and leaves the rock with more or less rounded crystals of hornblende projecting from it, and with an external appearance not unlike the nephrite coating seen, but very rarely, on a troctolite.* The rock is exceedingly tough, and very prone to decomposition, so much so that when a fresh surface has been exposed for about a year a more or less thick scale of decomposed material can be taken off. A fresh surface shows very fine cleavage surfaces of hornblende, and when the feldspar is not so prominent as usual the rock has almost the appearance of a pure hornblende rock. The feldspar usually has a faint greenish tinge, probably due to the proximity of the green ferro-magnesian mineral. After weathering has acted on it for a considerable time, as with the rock under the alluvial deposits of the claim, the hornblende becomes almost pea-green in colour, studded with white specks of decomposed feldspar. Ultimately a clay, bluish-green in colour, and of the consistency of putty, results.

Examined under the microscope in section, the rock may be said to exist in two varieties—(*a*) one in which hornblende is plentiful to the exclusion of augite, (*b*) one in which much augite is present.

The (*a*) variety consists of plagioclase and hornblende almost wholly. The plagioclase is usually quite fresh, and shows very pronounced polysynthetic twinning after both the albite and pericline laws. Karlsbad twinning was also seen in one or two sections. From the extraordinary number of lamellae and their marked development we should infer that the feldspar was very basic. A determination of the feldspar proved this conclusively. In the determination, as usual, a section was selected cut nearly perpendicular to the lamellae. This was to be recognized by the fact that the illumination of the two sets of lamellae was almost equal when the twin-line was parallel to a cross-wire. Several measurements of the extinction-angles were taken, with the result that the angle was found to be about 35° (or 55°). The feldspar, then, is an almost pure anorthite. That this is the case was also proved by an analysis of the rock, in which it was found that, while the amount of lime was very high, the amount of potash was exceedingly low (see later). The rock, therefore, is rather exceptional, for the general rule is for the feldspar to vary between oligoclase and labradorite. Inclusions are in some cases numerous, consisting of fluid pores and other kinds whose exact nature it was impossible to determine. A striking peculiarity with regard to these feldspars is the presence in some sections of a decided bending of the lamellae. This bending, too, is not altogether restricted to the plagioclase, for a section has been seen in which the augite (or diallage) seems to have been bent. This bending, we know, is a result of dynamic metamorphism, and it is probably here due to pressure subsequent to the solidification of the rock-mass after intrusion.

Hornblende.—This is uniformly green in colour in small plates, with usually no distinct terminations. Pleochroism is marked, from green to yellow. The extinction-angle varies between 13° and 15°; the plates are

* It is seen very conspicuously in ore from the west coast of Otago.

usually elongated in the direction of the pinacoid faces. No twinning has been seen. The hornblende is often much altered. The more usual alteration consists in the development round the borders of the plate of a secondary outgrowth of the mineral, causing an apparent extension of the plate. Another type not uncommon in the sections examined consists in a large development of chlorite, which is distinctly pleochroic, green in colour, and very ragged in outline. Now and again calcite and magnetite are formed in small quantities.

The (*b*) variety consists of plagioclase, augite, and hornblende. The plagioclase has characters exactly similar to those in the (*a*) type; the hornblende also much the same as before. The augite is rather peculiar. In some cases it seems to take the form of diallage, and with those cases in which it occurs to a large extent it would lead one to call the rock not a diorite, but either an augite-diorite or a gabbro. The diallage occurs in large plates with a more or less well-marked schiller structure formed by rows of inclusions, an extinction-angle of nearly 40°, strong orthopinacoidal cleavage, and with no pleochroism. The plates are also usually colourless, and the inclusions are often very numerous. Augite as distinguished from diallage also occurs. This is without regular outlines, with an extinction-angle of 35° (approximately), and quite colourless in section. Alteration, as with the hornblende, is sometimes pronounced. The usual type of alteration is the development of uralite. This begins at the border of the plate, gradually extending inwards, and frequently a ragged scrap of augite is enclosed almost entirely by uralite. The latter has only a very faint pleochroism. In another type of alteration chlorite is formed, and even calcite, just as in the case of the (*a*) type of rock.

The structure of the rocks presents characters strongly suggestive of dynamic action. On first looking at a section with crossed nicols one cannot help being struck with the "crushed" appearance of the rock. The whole section seems to be composed of a mosaic of small plates of feldspar and ferro-magnesian mineral placed in a curiously disorganized manner. The appearance is exactly the same as the granulitization seen sometimes in granitic masses, and is probably due to the same cause—*i.e.*, crushing of the rock-mass after consolidation.

Sometimes there is an appearance very like the groundmass seen in quartz-porphyries that are holocrystalline—namely, a very small mosaic—in this case consisting of altered hornblende or augite and little plagioclase plates.

An analysis of the rock runs as follows:—

	Per Cent.
SiO_2	47·40
FeO	6·60
Al_2O_3	18·17
CaO	12·23
MgO	7·17
K_2O	0·20
Na_2O	2·75
H_2O	0·75
Fe_2O_3	5·42
MnO_2	Trace.
TiO_2	Trace.

Note.—In this analysis the CaO was determined volumetrically with $KMnO_4$ standard solution. This was the method followed by the analysts of the coral limestone at Funafuti, and it certainly seems neater and just as accurate as the other way. On fusion of the powder with the fluxes

a greenish tinge was noticed, due, of course, to MnO_2, but the quantity present was too small to be worth tabulating. The TiO_2 was determined by the colorimetric method, but the quantity present was very minute, being also not worthy of tabulation.

W. C. Brögger, in his "Das Ganggefolge des Laurdalits," has given several diagrams of rocks based on their chemical composition, or, rather, what Professor Washington, in his "Quantitative Classification of Igneous Rocks," calls "molecular proportions." A consideration of the above analysis will show—(*a*) a percentage of silica which is exceptionally low—even too low for a diorite, but quite usual for a gabbro: (*b*) a very large percentage of CaO and Al_2O_3, and at the same time an exceptionally low one of potash; this shows, as has been previously shown from the extinction-angle, that the feldspar in the rock is almost wholly a nearly pure anorthite: (*c*) a rather high percentage of total iron and a truly high percentage of Fe_2O_3. It may be remarked that a more than ordinary amount of black magnetite grains were found in powdering the rock, and an examination of a section shows that magnetite sometimes occurs to a considerable extent.

Professor Washington, in his "Chemical Analysis of Igneous Rocks," gives (p. 286) the analysis of a hornblende-gabbro which runs as follows :—

	Per Cent.
SiO_2	49·80
Al_2O_3	19·96
Fe_2O_3	6·32
FeO	0·49
MgO	7·05
CaO	11·33
Na_2O	2·22
K_2O	0·61
H_2O	1·71

Note.—The analysis is marked A2II, so the results can be relied on.

Comparing this with the analysis of the rock in the claim, we see that, except for the low percentage of FeO in the former, these analyses agree very well. The claim, therefore, placed as nearly accurately as possible, will have the following position in Professor Washington's scheme of classification: "Class II. DOSALANE. Rang 4. Docalcic. Hessase."

It will be noted from the foregoing that the rock will be more accurately classed as a hornblende-gabbro or simple gabbro than as a diorite, though the latter name was given to it by Captain Hutton and Sir James Hector.

Considering now this rock only as far as regards the claim, we find above a series of strata of which a typical exposure is illustrated in the following section :—

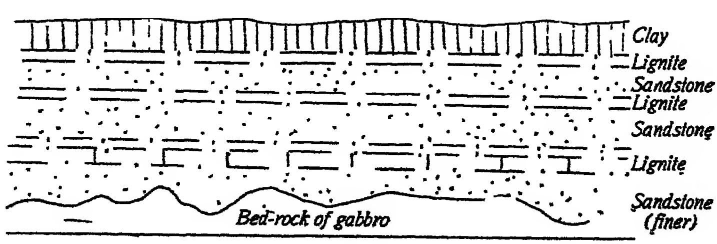


FIG. 8.

In this we see that, resting on the eroded surfaces of the bed-rock, there is first a layer of sandstone and silt about 5 ft. thick, followed by a stratum of lignite of about the same thickness; after this comes another stratum of sandstone, then a layer of lignite, and so on. Three distinct seams of lignite separated by beds of sandstone are to be seen. Above all is the clay, or in places the artificial tailings. The geology, therefore, of the claim is very simple. The sandstone on the bottom is usually fine, interspersed here and there with small pebbles. Sometimes fairly large pebbles of gabbro are found.

The lignite above is poorer in some places than in others, but generally speaking its value does not amount to much. That this lignite has drifted into its present position is shown unmistakably by the following: (*a.*) It is usually muddy, the woody tissue being interspersed with pockets of fine silt, or sometimes very similar in appearance to a brownish-black clay. (*b.*) Rounded pebbles of varying size, and consisting of gabbro, are found in it, more often than not in the bottom of the layer. (*c.*) Prone tree trunks and branches, consisting of miro, pine, and rimu, have been seen in it. (*d.*) An instance has been noticed where a tree-trunk has a vertical position in it, and the lignite has its layers bent up and around the trunk. Whether the trunk actually grew as it has been found is not known, but the probability is that it was simply sticking out of an underlayer, and a fresh deposit was formed round it. (*e.*) The bands are not continuous, but occur in some places and not in others, and often dovetail into the silt and sand. This would tend to show the existence of current bedding. The sandstone above the bottom layer of lignite is much the same as that below it, but does not contain, as far as can be seen, any pebbles. The thickness of the sandstone layers varies between 5 ft. and 20 ft. The beds are of only local extent, occurring only in the hollow between the two sides of sloping ground. The lignite (to a very small extent) and the sandstone are auriferous, a fact which can be shown in the case of the sandstone by a simple prospect with a shovel. No fossils of any kind have been seen.

What, then, is the origin of these formations? To answer this question, let us first suppose we have a coastal area like the Round Hill district undergoing submergence, while, of course, the land further in remains more or less stationary.* The first effect of this is to increase the corrosive action of the streams. Since, however, the land is mostly bush-covered, the corrosion will not be very great, but the amount of vegetation brought down will be proportionately increased. Again, as submergence goes on, the sea will invade the river-valleys, forming ultimately a bay or estuary, and it may extend even to some distance up the sides of the mountain-range. The water of the streams, charged with detritus and vegetation, on meeting the comparatively calm water of the bay will be unable longer to retain the material in suspension, and it will be precipitated. The result is that at first a bar will be formed, but later on the bar will be flattened out. The strata in the bar will be composed partly of silt and partly of woody material, according as the stream has brought more *débris* than vegetation, or *vice versa*. There will, therefore, be a tendency towards the formation of a flat plain, as the sea-action will round off all irregularities, and the slope will increase gradually inland. A succession of periods of flood will thus cause the formation of bands of silt, or vegetable matter mixed with silt,

* If depression all round took place, the corrosive action would, of course, be diminished.

or even in some cases nearly pure woody tissue, especially when the streams come from heavily bushed country. Again, as the land becomes more submerged, any ridges which may exist will be converted into headlands or capes, and in later stages even islands may be formed. Beach-pebbles will occur, of course, but these do not necessarily occur at the margin of the water; indeed, in the case of a bay it is probable that the pebbles will be deposited further out into the sea than in the case of open coast.

Next suppose this area, once submerged, is gradually elevated. The headlands and capes and islands will increase in size, the detrital deposits will appear, and finally a flattish plain will make its appearance, extending between the ridges and right up to the flanks of the range. The corrosive action of the rivers will be lessened, and deposition will occur further up the rivers, tending to increase the extent of the plain.

Let us now apply these principles to the district we are concerned with. Its physiography is exactly similar to that in the case we have supposed. In the sea beyond the mouth of the Ourawera occur small islands, and there are isolated peaks extending at intervals from Orepuki to Riverton. Between these is a succession of flat plains, with a gently rising slope from the coast. At the locality of the claim there are the detrital deposits before mentioned, and the whole range is densely bush-covered. We can therefore suppose that at an earlier period in the earth's history the coast hereabouts was depressed owing to continental oscillation or other causes; that the hollow or rounded surface of the bed-rock of the claim formed an old river-bed down which a stream from the mountains carried at intervals silt and vegetable growth, or both together; that a bay formerly existed where now the Ourawera discharges its waters into the sea, and that a long arm of comparatively calm and shallow water extended from the bay up into the river-valley. The stream then, on meeting the sea-water, would be compelled to precipitate the material it brought down, and the deposits of the claim would then be formed under the water.

The flattish coastal plain would also be formed about the same time. Later on an elevation of the land took place. The Ourawera, bringing down its *débris*, would have its grade lessened,* and consequently would deposit the material higher up, and would enlarge the plain, besides covering its upper part with river-pebbles. The strata formed under the sea-water would now appear close to the base of the range. Bush would grow over all the plain, and the appearance it now presents would be formed. On this theory, the elevation cannot at present be completed, or there was a former much greater elevation of the land, which extended further out than it does at the present day, for, as we have previously remarked, islands occur out in the sea just beyond the mouth of the Ourawera, and these are distinctly not volcanic. Further, the river must have been much larger than it now is, otherwise it could not have deposited such large masses of lignite as do actually occur—such as seams 5 ft. thick after compression. It is possible, however, that it was assisted to some extent in this respect by wood washed along the former shore and banked up in the quiet bay.

It has been assumed that a submergence followed by an elevation occurred, or, rather, as the river-bed shows, first a greater elevation than now, then a submergence, followed by a smaller elevation than before, which latter may still be going on.

* With reference to the coastal district only; as before, the inner portion remaining steady, or nearly so.

Proofs that the land was formerly much higher, especially in the south, are given by the following: (*a*.) The outlying islands have a fauna and flora very similar to that of New Zealand, and must have been connected to the mainland in late Tertiary times. (*b*.) The absence of older Pliocene marine formations in both Islands, and the absence of nearly all Pliocene formations in the South Island: what Pliocene formations do occur are wholly gravels, which would naturally be formed in the denudation of a mountain-range. (*c*.) Further, the submerged valleys on the west coast of Otago, in the Sounds region, show that formerly the land was much higher, for if, as is most probable, the actual shape of the bottoms as shown by soundings has been caused by glacial erosion, it is evident that a great elevation must have once taken place.

That a former subsidence of level in the South Island has taken place, probably in the Pleistocene, is shown by several writers. On the west coast of the South Island, according to Dr. Hector in the Geological Survey Reports, 1866–67, comparatively recent sea-beaches or beach-terraces extend to more than 220 ft. above the sea. Mr. Dobson, another observer, has estimated these terraces at 400 ft. (Trans. N.Z. Inst., vol. 7, p. 444). At Amuri Bluff, on the east coast of Canterbury, there are three distinct terraces, and Mr. McKay obtained Recent marine shells from the highest, which he estimates to be 500 ft. above the sea. These three terraces also appear further south. Further, a deposit of fine silt occurs along the east coast of Canterbury and Otago from Banks Peninsula to Moeraki. Its lower portions are stratified, but its upper ones are not. At Oamaru the gravels at its base contain large numbers of Recent marine shells, and the upper parts have yielded moa-bones. This silt goes to a height of 800 ft. at Banks Peninsula, and to 500 ft. or 600 ft. at Oamaru. Further, the entrance to the West Coast Sounds has been terraced to a height of 800 ft. above sea-level. Finally, the remarkable river-terraces found throughout the South Island all furnish collateral proof of a once lower level. It is to be noticed that these instances also show a subsequent elevation of the land, and it is quite possible that this elevation is still going on.

The topmost height of the actual detrital deposits amounts to between 400 ft. and 500 ft. It is quite possible, therefore, that the depression or submergence of which instances have just been given lowered the level of this part of the country also by 500 ft. The claim deposits would then easily be accounted for.

HISTORY OF THE CLAIM AND PLATINUM.

It is in a district having the characteristics just described that the company at present called the Round Hill Hydraulic Sluicing Company has its working-area. The main facts about the claim and the discovery of platinum are as follows: Somewhere about the year 1880 some prospectors working in the neighbourhood came upon what they believed to be good alluvial gold. As usual, though the district was in a dense bush and without even the crudest means of outside communication, claims were soon pegged off in great numbers, and in a very short time a considerable number of men (about four hundred), mostly Chinese, were engaged on the field. For a short time the yield was decidedly good, but at last, despite great exertions on the part of the European part of the population (for the Chinese soon made off), barely enough gold could be got to pay expenses. Recourse was then made to hydraulic sluicing, by which, of course, the quantity of material "washed" would be enormously increased. A company was formed, with

a head office in Liverpool: the water-races formerly held by the individual miners were all bought over; three elevators were soon put in working-order, and in 1891 sluicing on a fairly large scale began, and has continued up to the present time. Some idea of the extent of the field may be got when we consider that up to 1898 the amount of ground worked by the company was 33 acres, representing 2,100,000 cubic yards of material. The yield of gold for the same time has been 7,751 oz. 16 dwt., equal to a recovery of 1⅞ grains per yard, or in value to 3½d. per yard. The total length of all the races amounts to seventy miles, and the total carrying-capacity amounts to thirty-six Government heads of water. The elevators are capable of lifting to a height of 50 ft., and they elevate about 70 tons of material per hour.

After sluicing had been going on for some considerable time, the manager, who is of a decidedly curious turn of mind, began to notice that after washing up he got, in addition to the gold, a small quantity of a silvery-white mineral in fine thin scales. Though somewhat struck with the discovery, he took no further notice of it until, having at length sent some to the Bank of New Zealand at Riverton, he was informed that it was platinum, and well worth saving. The bank agreed to give him £2 an ounce for it at first. After every subsequent wash-up, therefore, the platinum was separated from the gold by amalgamation and was sold, but it was not until about 1897 that any was saved at all. All record of the amount got from the field before this date is thus hopelessly lost.

It has been estimated that the average annual yield of gold from the claim is now about 2,000 oz. The yield of platinum to date could not be got accurately, but we have been informed that an average figure representing the amount got from this locality alone is 150 oz. per year. This would make the total quantity saved to date about 1,200 oz., an amount which is probably in excess of that actually sold.

It must not be supposed that this is the only place in the neighbourhood where the metal is found. We have already mentioned the fact that it was found as far back as 1878 at the mouth of the Waiau, and it has long been known that it occurs on all the beaches from that river as far as the Orepuki Beach. The quantity, of course, is small, and the scales minute and thin, but it evidently pays to collect it. After every severe storm it is not an unusual thing to hear of miners prospecting the beaches for gold, and returning not only with gold but with a fair quantity of platinum.

An examination of the gravel-deposits and the sand shows that the minerals most commonly associated with the metal are chiefly garnets and small grains of non-magnetic or but slightly magnetic iron-oxide. In the claim ordinary strongly magnetic magnetite also occurs.

It will thus be seen that the second occurrence of platinum in Otago is in the alluvial plain of the Round Hill district, and to a smaller extent along the beaches from the Waiau to Orepuki. No records have been made of any occurrence on any other beach to the east, though it is quite possible that traces of it may be discovered, for the beaches as far as Riverton are more or less covered with ripples of ironsand, and this is especially prevalent with the platinum at Orepuki.

Seeing that the platinum from the beaches is essentially the same as that from the claim, one description will do for both occurrences. The metal almost invariably occurs in the form of round or oval thin plates or leaves. Rarely we find small rounded grains, and it has been stated that crystals also occur. W. S. Hamilton, in a paper on the discovery of these so-called crystals read before the Southland Institute in 1886 (see Trans. N.Z. Inst., vol. 18, p. 402), says that he obtained from the Orepuki

sands several crystals which, to use his own words, were minute but tolerably perfect. The form was a square tablet, perfect on three sides, but irregular on the fourth. With regard to this, we may say that, though we have examined a considerable number of scales and samples, no such form has been discovered, or, indeed, any approaching to it, and, as it has never been mentioned since, the probability is it is a mere peculiarity arising from sea, river, or pebble action. The scales are slightly magnetic, often of fair size, some having a surface as large as that of a large pin-head. Usually the surface is covered with several intersecting series of striae.

Search has been made in Dr. Reinhard Brauns's "Das Mineralreich," but nothing of any great importance was found, as far as the present paper is concerned, on the subject of platinum. Following however, his example and that of several other investigators, amongst whom we may mention Professor J. F. Kemp, we took a typical scale, and, after carefully polishing it, subjected it to an etching process In this the solution used was a mixture of nitric and hydrochloric acids, and the strength of the etching-solution was systematically varied. The scale was first of all immersed in a solution of one part of aqua regia to eight of water, and treated carefully for a quarter of an hour. It was then washed and examined in reflected light. No alteration was, however, found. The strength of the solution was then increased gradually from one part in eight of water to one part in two of water. With this solution, after heating gently for half an hour, etching was noticed, but to a small extent. Lastly, a solution of one part in one of water was used; the surface then became decidedly etched, but no definite pattern was formed, so that it was not considered worth while to photograph it. This result shows that there can be no mechanically included gold in the scale, for the gold would disappear with comparatively weak acid. It is also proved conclusively that the opinion expressed by W. S. Hamilton in the paper above referred to—that the striae are caused by the scale being built up of a number of smaller crystals—is without foundation. For if crystalline structure were present the etching would be sure to give evidence of it in the formation of a definite pattern.

ANALYSIS OF THE METAL.

In all investigations into the occurrence of platinum in different localities an analysis is of importance from both an economic and a purely scientific point of view. The composition of nuggets, grains, or scales has been found to be very different in different countries, and several general rules can be founded on a comparison of the different results. It will be interesting and instructive, therefore, to compare our results with those already obtained by different investigators. The method adopted was a slight modification of the one devised by Deville and Debray.

The results obtained from the analysis of the platinum-alloy were as follow:—

	Per Cent.
Platinum	74·61
Iridium	1·30
Palladium	1·36
Rhodium	3·52
Gold	0·39
Iron	5·08
Copper	0·15
Iridosmine (osmiridium)	14·32
Osmium	Trace.

Let us now compare these results with those obtained by Professor J. F. Kemp, as tabulated in his pamphlet on the "Geological Relations of Platinum" (see Bulletin of U.S. Geological Survey, No. 193). Professor Kemp has here collected the results of forty-two analyses of platinum by various chemists, and has arranged them in a series of curves in which percentages of platinum form the abscissae and those of other metals the ordinates. On examining the table and analyses it will be seen that, generally speaking, there seems to be a kind of rule with regard to the amount of osmiridum present and that of the pure metal present, the one increasing as the other decreases, and *vice versa.* The same relation seems to hold in the case of the iron present. It will be noticed that on no occasion when the percentage of platinum in the alloy amounts to 70 does the amount of osmiridium exceed 10·5 per cent., and that percentage occurs only in one specimen. Further, where the amount of osmiridium is relatively small the amount of iron is fairly large, but where the osmiridium is in large quantity the iron falls very low. Thus with a percentage of IrOs (iridosmine) of 6·36 the amount of iron is 15·58, but with 25 per cent. of IrOs the iron falls to 4·30 per cent.

In looking now at our analysis some remarkable peculiarities are at once evident. In the first place, there is platinum amounting to 75 per cent., yet the amount of osmiridium is very high—14 per cent. This is a direct contrast to the results of Professor Kemp's conclusion; indeed, only one analysis at all similar to it has been found. It is given in Dana's "System of Mineralogy," the sample being from British Columbia, and having the following proportions: –

	Per Cent.
Platinum	68·19
Iron	7·87
Palladium	0·26
Rhodium	3·10
Iridium	1·21
Copper	3·09
Iridosmine	14·62

There is another from the same locality having IrOs equal to 10·51 per cent., with platinum 72 per cent.

Further, in all the analyses where platinum amounts to between 72 and 76 per cent. the iron amounts to not less than 10 per cent., whereas in the Orepuki metal it reaches only to 5 per cent. The amount of rhodium present is also high. It will also be seen that a fair amount of gold was shown to be present; but it must be remembered that this was identified only by loss on treatment with acid, and, as the estimation by loss is not quite reliable with very small quantities, it is probable that the amount is not quite so much. The other constituents are, however, in very fair accordance with the results got for them by other writers.

An analysis was also attempted of the osmiridium residue. By Claus's method the percentage of iridium was found to be 59·63. Further separation was not effected.

Origin of the Platinum.

Owing to the interest quite recently awakened with regard to the geological relations of the platinum discoveries, a large number of places —with a more or less technical description of them—where the metal has

been found have been recorded. It will be advantageous in our investigation to first briefly review the records hitherto noted of the principal occurrences.

Nearly all discoveries can be grouped roughly in three large classes—(1) veins, (2) placers, (3) eruptive rocks.

In veins the discoveries are few, and rather remarkable. The chief one is that noted by Professor W. C. Knight, from the Rambler Mine, in Wyoming. The district has a country rock of gneiss-granite, penetrated in several places by large dykes of dark basic rocks. The dykes are composed mostly of a typical diorite, and it is in the outcrop of one of the dioritic intrusions that the mine is worked. It is also to be noted that, so far as is known, the metal or ore does not occur at all beyond the region of the intrusion.

The second noteworthy occurrence is reported by C. F. Hartt, from Brazil, in South America. The country rock here is described as a syenitic gneiss cut by quartz veins. Nothing further is known about it.

Another interesting discovery is noted from near Seville, in Spain, by the French chemist Vauquelin. The metal was found in a mineral containing copper together with antimony in an undoubted vein, which was actually being worked for silver. The country rock is a mica-schist.

Again, a remarkable occurrence, which we have already mentioned, is reported from New South Wales. The metal was found near Broken Hill, the seat of the great silver-mines of Australia. The localities where the metal has been found are described as consisting of schists, gneisses, and quartzites, all of which are highly altered sediments. Intruded into these in various places are dykes and bosses of granite and very basic diorite. Some serpentine occurs within a distance of seven miles. The actual lode has already been described. The platinum occurs here in very minute specks, incapable of being distinguished by the eye. It has been suggested that the metal owes its presence to hot springs which formerly issued from the lode, the metal being absorbed by the clays and kaolin round the vein.

Lastly, attention must be directed to the New Zealand lode in the Auckland Province, at the Thames goldfields. A reference to the parallel drawn between the Longwood and the Coromandel Peninsula shows that the lodes in this instance are also in a district penetrated by dykes of diorite or dolerite, though the actual veins are of quartz.

With regard to the third class—*i.e.*, in eruptive rocks—since all placer deposits are derived more or less from igneous rocks or mountainous sedimentary formations, it will be sufficient to describe the most common placer deposits, referring them where possible to their original mother rock (igneous or otherwise).

Platinum has been obtained in commercial quantities in connection with the gold-washings of south-western British Columbia. As far as the metal is concerned, the area which is of special importance is in a valley of a small creek along the Tulameen River. In the neighbourhood of the creek a large dyke of peridotite crosses the country, but does not extend to any great distance beyond. It is cut short by a rock of pyroxenite type, which in its turn is replaced by a large mass of andesite. Evidently, then, the gravels are formed from either the peridotite or the pyroxenite. A careful examination of some nuggets which occurred amongst the scales of platinum revealed the presence of chromite, and, in a few cases, of pieces of olivine. Later on a nugget was got with pieces of pyroxene adhering.

This strongly suggested the fact that the metal came from both rocks. Assays made of the rocks distinctly show traces of platinum, though no grains were large enough to be visible to the naked eye. It appears from this that here the mother rock of the metal has been distinctly identified, and it is well to note the character of the two rocks.

A very similar placer occurrence is reported in connection with the gold-washings of Columbia. The district, which is near Bogota, is formed of the detritus of two rivers flowing from a ridge which is itself an offshoot from the Andes. As far as can be gathered, the country rock is a syenite or syenitic gneiss, with a little granite and much metamorphic rock.

The most notable formation of this kind is, however, the Ural region of Russia. The actual deposits are found on the eastern slopes of the range, and are limited to two localities—the valley of the Iss River and the vicinity of the Town of Nizhni Tagilsk. Both regions are old land-areas which have suffered protracted surface weathering and degradation. The drainage has reached a base-level, and consequently the concentration of heavy minerals has been extreme. The rock-formations along the Iss are almost exactly similar to those along the Tulameen, in British Columbia. Near the head of each stream are extensive outcrops of peridotite associated with equally large areas of syenitic gneiss. Smaller exposures of diorite, gabbro, and gabbro-diorite also occur. The other formations further down are of no practical importance, since the river into which the Iss flows derives nearly all its water from its tributary. To trace this platinum to its mother rock Professor Saytzeff carried out some investigations. The result of his tests shows that the peridotite is the chief source, but the metal also occurs to a small extent in the gabbros.

The Tagilsk region is exactly similar to the above, with peridotites, gabbros, and diorites.

Again, it was noted in 1870 by a Russian observer that the metal occurred in Lapland, and the consensus of opinion seems to be that it was in this case also derived from a peridotite.

Borneo can also be cited in this connection. Platinum was found here in gravels from a series of mountains which consisted of serpentine, diorite, and gabbro.

Just lately, too, it has been mentioned in the "Transactions of the Institute of Mining Engineers," or more particularly in a paper by E. Glasser on the "Mineral Wealth of New Caledonia," that platinum occurs in placers on the Fly River, and these placers are, according to Glasser, derived from the denudation of the great serpentine "massifs" which occur in the neighbourhood.

Besides these occurrences, there are several exceptional ones reported from different countries.

Beach-sands have been found on the Oregon coast to yield very high percentages of the alloy as compared with gold.

In Brittany, in France, the metal has been got with tin-bearing sands along the coast; and in the latest issue of the Geological Survey Proceedings of Queensland mention is made and assays given of beach-sands along the coast which contain quite an appreciable amount of the metal.

Finally, an extraordinary case has been recorded of the presence of metals of the platinum group in the ash of some Australian coals. Such an occurrence has been recorded from no other district, and an assay shows that the ash is quite the richest ore yet assayed for platinum.

What, now, can we gather from these discoveries? If we look back for a little at the geology of the claim we shall see that the characteristics of it are—(*a*) beds of lignite, (*b*) a base of gabbro rock which is an intrusion into a clay-slate formation, (*c*) a gravel placer or beach formation. From the review just given it will be evident that any one of these masses could be not only a repository, but, in the case of the gabbro at any rate, an original habitat of the metal. It was therefore necessary to examine and test both the lignite and the rock in a very thorough manner.

A mass of the lignite was burned completely to an ash, and when a sufficient quantity of ash remained a charge was made up as follows (crucible fusion) :—

	Grains.
Ash	100
Soda	125
Borax	20
PbO	60
Argol	5

After cupellation an examination of the cupel showed the merest speck of gold, so small as to be unweighable.

It was not thought worth while to follow up this line any further, because, since the lignite is a detrital formation, and as it was brought down by waters which also brought down masses of the neighbouring rock, and since it was probable that more platinum would be evidenced in the rock than in the lignite—for these reasons it seemed better to devote attention to the rock.

A microscopic examination of several sections failed to show the faintest trace, either in reflected or polarized light, of any isotropic mineral other than magnetite. Recourse was then had to assays.

A portion of the rock was taken clean and crushed in a piece of clean cloth. When fine enough, two charges were made of it, as follows :—

A.

	Grains.
Rock-powder	1,000
Soda	1,250
Borax	500
PbO	500
Argol	50

B.

Rock-powder	1,000
Soda	1,250
Borax	600
PbO	600
Argol	45

After crucible fusion, scorification, and cupellation, the weights of the beads were found to be—A, 0·003 grain; B, 0·003 grain. Since, however, some decomposed material adhered to the rock, fresh assays were run with exactly the same charges. The bead of A weighed then 0·001 grain, and that of B 0·0012 grain. Both beads were then put together, inquarted and parted in nitric acid, dried, and the combined weight got. It amounted to 0·002 grain.

From this it will be seen that the whole was practically pure gold, with only a trace of silver, and that probably due to the lead-oxide used.

An amount equal to 0·002 grain in 2,000 grains of powder works out at nearly 16 grains per ton. Taking the price of pure gold at £4 per ounce, this means that the rock is worth 3s. per ton, so that it is decidedly auriferous, and might even pay to crush. When we consider, then, that the *débris* of the claim has been the accumulation of perhaps hundreds of years, when we consider that the sandstone of the claim is auriferous, that the washdirt of the miners consists of a mixture of decomposed rock material and sand with pieces of lignite, and so on, and when we consider that more gold is found where the rock is most decomposed, it would appear that much of the gold of the company comes from this gabbro rock. This is further suggested by the fact that the value of the gold fluctuates between £4 2s. 6d. and £3 16s. 6d. per ounce, for it is well known that gold from igneous rocks is usually very pure. The impurities, or the gold of lesser value mixed with it, may have come along the beach, for it is also well known that the gold which does occur on the beach at Orepuki and at the mouth of the Waiau is inferior in value, amounting rarely to more than £3 10s. per ounce. The appearance of the gold in the claim also strongly suggests a different origin from ordinary reef gold. The grains are very small, and there is no record of a nugget of any size ever having been found near the claim. An examination in reflected light shows that many of the grains are irregular, rounded sometimes but at others almost rectangular, and with ragged edges. It would thus seem that they had to some extent been washed along by a running stream, while others had been freed just where they are. It was appearances like these which led McKay, in his "Gold-deposits of New Zealand," to say, "On the Orepuki and Longwood Range field no payable quartz lodes have been found, and the alluvial gold had a source distant from where it is now found. In this case the alluvial gold does not indicate the existence of reefs in the neighbourhood." As it is to be hoped we have shown, it is quite possible for the gold of the claim to have come from the rocks (gabbro) in the neighbourhood, washed down and concentrated from the hills near at hand when a larger stream was flowing.

In connection with the gold which we consider to have been, to some extent, washed along the beach, it is just as well here to consider the opinion expressed by W. S. Hamilton in the paper previously referred to on the renewal of gold on the beaches of the south of Otago. He says, "Just as wood is often silicified into stone in large quantities, or carbonized into coal, so it would appear that it may be metallized into the ironsand of our goldfields, auriferous, cupriferous, or platiniferous, from either some obscure conditions of process or inherent quality of the original substance. The ironsand of our goldfields appears to be derived from the breaking-down of pyritized wood by mechanical or chemical means. This pyritized wood occurs along the sands, and, by the replacement of the sulphur by oxygen, magnetite may easily be formed from timber." He then goes on to say, "The renewal of gold in our beaches seems to be an example of this slow change of the ironsand. Miners observe the same renewal in the washings of the Orepuki Goldfield." This theory of renewal is, of course, mere nonsense, for it is a well-known fact that in all beach-workings the world over more precious metal occurs after heavy storms than was present before. The reason is that the gold, being very heavy, requires a great force to move it away, and this force is provided by the fury of the waters, while the lighter material on top is easily carried off, leaving the gold uncovered.

Several distinct assays were then run of the rock-powder; the beads were put together, so that a total weight of 0·02 grain was obtained; the

whole was inquarted and parted in nitric acid as before, care being taken to use only a minimum of silver to prevent any loss of other metals which might be present. After parting and drying, the bead was again weighed. Its weight amounted to 0·0195 grain. This strongly suggests that no metal except gold was present in the rock, for, although a small difference in weight (0·0005) was obtained, this could never be regarded as conclusive.

To remove, however, all element of doubt with regard to the presence or otherwise of platinum in the rock, recourse was had to the following method: A large mass of perfectly fresh rock weighing over 4,000 grammes (nearly 10 lb.) was taken and carefully powdered. The pestle and mortar used was first rendered perfectly clean, and the preliminary crushing of the rock was done in new cloth, so that all danger of introduction of any foreign materials whatever was done away with. After crushing had been gone on with until the powder was fine enough to go through a 60-mesh sieve it was panned off. By this means all the lighter portion of the powder was gradually carried off, and ultimately there was left a mass of black material about 30 grammes in weight. This was carefully examined by means of a microscope for any trace of the silvery metal, but none was found. Since, however, the result of most observations on the occurrence of the metal in igneous rocks tends to show that it is present in them in exceedingly fine division, the concentrates were subjected to a process as follows: A quantity of aqua regia was added to the porcelain vessel containing the residue, and the liquid was evaporated to dryness on a water-bath. This process was carried out two or three times, to insure the solution of any metal present. The residue (from the evaporated solution, not the original residue) was then twice treated with sulphuric acid, and again evaporated to dryness on a water-bath. This residue was taken up with absolute alcohol and water, filtered, more alcohol was added, and to the clear solution was added ammonium-chloride crystals in excess. The solution was slightly warmed to dissolve the crystals, and put aside for twenty-four hours. On examination at the end of that time no trace of a precipitate was visible, and, though the liquid was again filtered, absolutely no trace of the yellow chloroplatinate was found. Care, of course, had been taken not to have too much liquid when the ammonium-chloride was put in, for in that case a small quantity of platinic chloride, even if present, might not be precipitated.

From results got from assays, and from qualitative tests for the metal, we are forced to the conclusion that it does not occur naturally in the gabbro. There is, of course, the very remote possibility that the metal occurs so sparsely distributed in the rock that the actual piece taken really contained none. The assays, however, were all done on pieces of rock broken from different places, and if there had been any present we should have expected a small, yet distinct, indication. It is unlikely, too, that a piece of rock 10 lb. in weight from the heart of the claim should contain no trace of metal if it were really present in the rock.

Where, then, does it come from? The clay-slate formations of the range can be dismissed as far as the claim is concerned, for the present stream does not flow through them, nor could it have been possible for even a large stream to have done so. The cause of the stream being larger was not a greater length, of course, than it now has, but an elevation of the land causing a greater rainfall and thus increasing the water-supply without lengthening the course to any extent. The stream everywhere flows through gabbro rocks until reaching the plains.

There seems to us only one other possible explanation—*i.e.*, that the platinum was formerly present as a beach deposit which was subsequently covered up by the detritus from the land brought down by the rivers. Such beach deposits are by no means unusual, as we have just previously shown in our review of the methods of occurrence, instances having been reported from Oregon, Queensland, New South Wales, and so on.

The origin of the beach-sands is conceived to be as follows: At the period when the level in the south of Otago was much lower the erosive action of the rivers in the neighbourhood would be greatly increased, seeing that a larger fall would be provided for their waters. The interior would, of course, have to be comparatively stationary, and observations in nearly all areas in which elevation and depression of coastal beaches have been observed tend to show that the interior does remain more or less stationary. The Waiau River would be affected in this way. We have already seen that it is a very large river, with an output equal to two-thirds that of the Clutha. If we examine its course from the time it leaves Lake Manapouri we shall see that it receives tributaries from the Hunter Mountains, from Lake Monowai, and from the Takitimu Mountains. During a period of depression, therefore, the erosion of these areas would be greatly increased, and, since the rate of flow of the river would be greater, its carrying-capacity would also be much greater. Consequently, at the mouth, which would be further inland than it now is, much of the gravel would be deposited, the remainder being deposited all along the banks. The material at the mouth, by the action of the waves, would gradually be distributed along the coast, so that everywhere along the borders of the land a bed of gravel and silt would be formed. This would include minerals derived from the rocks, the heaviest of which would first be dropped, and the others in the descending order of their specific gravity. The probable existence of a beach at Round Hill has been dwelt on already. On to this beach the finer of these minerals would be carried. It is conceived that the platinum has been brought in this way down the Waiau, and distributed along the beaches.

Let us now examine the evidence in support of this supposition. In the first place, the rocks from which the River Waiau flows would have to be platinum-bearing. If we examine the geology of the west coast of Otago we see that almost the whole of the left bank of the Waiau consists of the Manapouri formation of Hutton and the Kaikoura formation of Hutton. Hutton, in his "Geology of Otago," in describing the former, says that it is found only on the west coast of Otago from Milford Sound to Preservation Inlet, extending inland to Lakes Te Anau and Manapouri and to the upper part of the Waiau. The rocks, he says, are composed of syenitic gneiss, granulites, hornblende-schists, serpentine-schists, and limestone (marmolite). Dr. Hector, in describing the same, says that they are hornblende-schists, felstone dykes, and serpentines. The latter, he says, wrap round the formation, and in places are found on its surface. Again, Hutton, in his "Geological History of New Zealand" (1899), refers to these rocks as eruptives. He calls them chiefly diorites and gabbros that have acquired a schistose structure by pressure. He says they are coincident with the peridotites and serpentines occurring at intervals between Milford Sound and D'Urville Island. The Takitimus, from which also tributaries come to the Waiau, are placed by Hutton in his Kaikoura formation, which has been described by Dr. Hector and Mr. S. H. Cox as filled with dykes of diorite and serpentine. It is thus evident that the river comes from a

district in which serpentines and highly basic rocks are not uncommon. These serpentines have been connected by Hutton with the serpentines in Nelson, and indirectly with those of Milford Sound. It will be noted that platinum has been found in the serpentine district of Nelson, and it has been found actually in the peridotite rock north of Milford Sound. It is therefore quite conceivable that it may originate from this serpentine or diorite rock near Manapouri, for results go to prove that the metal is most often found in districts which are characterized by the presence of these rocks. In New Zealand alone we have already seen that there are three distinct occurrences, all associated with either a serpentine or a peridotite which alters into a serpentine. It was for this reason that attention was called to the occurrence in the Takaka Valley, in Nelson.

In the second place, the theory presupposes the existence of a more or less powerful current in Foveaux Strait, which would aid in the dispersion of the gravel along the shores. A reference to the accompanying

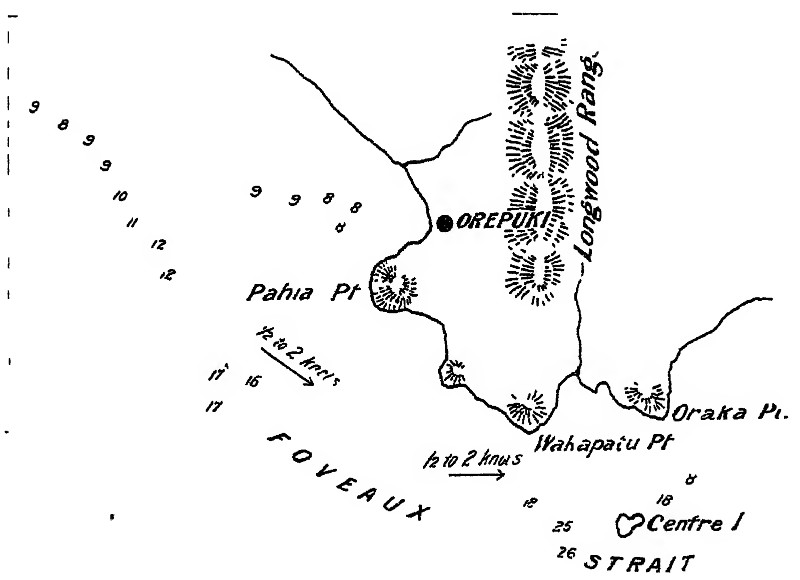


FIG. 9.

sketch, which has been directly copied from the Admiralty chart, affords ample evidence of the existence of such a current. From the sketch it will be seen that a current sets in from west to east, and flows with an average speed of from a half to two knots per hour. This would be sufficient to produce the easterly distribution of the pebbles observed on the beaches from the Waiau to Orepuki. The sketch is on a reduced scale, and soundings have been introduced, which show the gradual slope continuing well into the sea.

Further, the shape of the coast-line in the upper part is exactly what would be produced by gravel-deposition — a long low flat pebbly plain densely covered with bush. In its lower part it suggests to some extent the former existence, or even the present existence, of great denundation

by heavy sea-action. All the projections, such as Pahia Point, Oraka Point, Wakapatu Point, are denuded on their western sides, and the sea takes a bend round their eastern sides, forming a comparatively quiet bay. All the beaches down to Wakapatu are strewn with pebbles, and an examination of these pebbles shows that they consist of pegmatite, granite diorite, and a white mica-schist. These rocks all occur on the western bank of the Waiau, and are not found anywhere on the intervening country.

The fact that hardly any platinum has lately been found on the coasts past Orepuki also strongly supports the theory, for owing to its high specific gravity the metal would be amongst the very first to be deposited, and so would, in ordinary circumstances, not be carried far. Further, the metal has been found at the mouth of the Waiau not only in finer scales, but in nuggets weighing 2 oz. or 3 oz. These would naturally be dropped as soon as the velocity of the stream, from any cause, began to slacken; or, rather, as soon as the fall of stream began to be not so great these would ceased to be rolled along the bed.

It must be remembered, too, that in the Orepuki district the metal occurs chiefly in the form of scales. These are especially capable of being transported by water owing to the flatness of their surfaces, and the large amount of surface therefore exposed to any propelling agency.

Lastly, the theory affords an easy explanation of the fact that the platinum in the claim is found invariably on or very near to the decomposed outer zone of the gabbro bed-rock. Owing to its weight it would be deposited first of all on the beach-sands, nor would it be as liable to subsequent removal by water-action as the sand above it. Of course, even if it had come from the gabbro rock, and had been at first located in, say, the sandstone, it would ultimately reach the bottom in accordance with the principle observed in almost all alluvial areas—*i.e.*, the (so to speak) burrowing-action of the precious metals by which they work their way down from the highest level until they are stopped by impenetrable material.

It may here be stated that W. S. Hamilton considers the origin of the platinum as identical with that of the gold—viz., the "metallization" of wood into a platiniferous substance, from which the metal is derived by some oxidation or replacement. This, of course, would presuppose the existence of platinic solutions, or salts of platinum capable of being volatilized, quite near to the locality. With regard to this, Professor Meunier has stated that by introducing volatilized chlorides of iron, nickel platinum, &c., together with hydrogen, into a porcelain tube heated to redness and containing fragments of pyroxene, olivine, or rock, he is able to deposit the metals or alloys of several metals in the interstices in such a way as to imitate closely the natural occurrences. He therefore concludes that the native platinum has been brought in presumably a similar manner, and has been deposited so as to yield either nuggets or grains (see "Comptes Rendus de la VII Session Congrès Géologique International," p. 157).

It certainly is rather interesting to know that metals or alloys can be deposited in this way; yet crystallization from fusion seems not only to be as competent to bring about the observed results, but also to have much greater claims to probability and to general confidence.

With Hamilton's theory, too, the question why twigs alone have been chosen as the basis for "metallization" requires an answer.

To sum up: We have seen that this, the chief occurrence of the metal in the South Island, is in an alluvial district near the sea-coast, with a gentle slope towards the sea-beach, and situated at the base of the most outlying spurs of a mountain-range. We have seen that, contrary to what was to be expected, the platinum does not originate from the gabbro rock directly above which it is found, and which occurs all over the neighbourhood. We have given reasons for believing that it may originate in the serpentine region near the head of the Waiau, a region from which most of the tributaries of the river derive their water; and we have endeavoured to show that if such be the case it would be quite possible for the metal in the form of fine scales to be swept or worked along the beaches, and ultimately find itself in the position it now occupies. If the theory is true it will be quite in accordance with observations made in platiniferous regions the world over, though it must be admitted that the fact that the metal actually occurs as a constituent of beach-sands derived from a source far distant, and does not originate in the basic rocks which occur all round it, is quite peculiar, and one might almost say unique.

From the economic standpoint, if the case is as we suppose, the value of the discovery cannot be very great as far as the mother rock is concerned, for ages of denudation and concentration will be necessary to make even alluvial deposits payable, and it is almost impossible to think that it would pay to crush a mother rock which furnishes, even after a tremendous length of time, detritus giving such comparatively small returns. The theory, however, enhances the probability of further discoveries of heavy particles of the metal towards the mouth of the Waiau.

LITERATURE.

It only remains now to give a synopsis of the literature to which we have had access, and in this connection especial mention must be made of the paper on the platinum group of metals by Professor J. F. Kemp (see below). The references are divided into two groups—(*a*) those relating more to the geology of the country; (*b*) those relating more particularly to platinum.

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"Quarterly Journal of the Geological Society," 1885, pp. 212–13.
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(*b*.) *Platinum*.

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"Das Ganggefolge des Laurdalits." W. C. Brögger.
"Chemical Analyses," p. 446 *et seq*. W. Crookes.
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Art. XLIII.—*Petrological Notes on Rock Specimens collected in South Victoria Land*.

By Richard Hansford Worth, Assoc.M.Inst.C.E., F.G.S.

Comunicated by T. V. Hodgson, F.L.S.

[*Read before the Philosophical Institute of Canterbury, 7th December, 1910.*]

This paper embodies the results obtained from an examination of material collected in South Victoria Land by Mr. T. V. Hodgson, biologist to the British National Antarctic Expedition (1901–1903). It is merely intended as a supplement to the official report, and is confined to description of individual specimens, without any attempt to generalize or arrive at large conclusions as to the structure of the district. From a much greater mass of material the affinities of the various rocks have been worked out by Dr. Prior, and it is only where the specimens have not been described in the official report that any detail is entered upon, except that in some instances slight variances have been met to which attention has been given.

The following rocks are either not dealt with in the official report, except perhaps in some instances macroscopically, or show variations in the slides now prepared and examined. The details as to locality and general accounts of occurrences are furnished by Mr. Hodgson.

Castle Rock.—1. camptonite in so far as it contains amygdaloids of analcime.

Termination Rock.—3. trachyte.

Sultan's Head.—3. pumice.

Erebus.—1, trachydolerite; 3, diorite. 4, felsite.

Turtle Island.—2, trachyte; 5, augite nodule without olivine.

Inaccessible Island.—1, augite-andesite; 2. phonolitic trachyte, undescribed in detail; 3, trachyte.

Black Island.—1, diorite: 3, quartz-felsite; 4. sandstone; 5, quartzite; 6, camptonite; 7. augite-diorite: 8. camptonite: 9, micro-pegmatite; 11. augite-diorite; 13, 14, altered sedimentary, here described in detail; 16.

Brown Island.—2, basalt; 3, andesite; 4, basalt.

Western Mountains.—1, mica-schist; 2, dioritic lamprophyre; 6, tuff.

Granite Harbour.—1. felsite; 2, quartz-diorite; 5, quartz-mica-diorite.

In some instances a description of the rock has been given, but no specific or varietal name applied. Such omission is probably unimportant in any event, and must be taken as indicating that analysis as well as microscopic examination might be desired.

OBSERVATION HILL

Dark-grey trachytic rock, with phenocrysts of augite up to 3 mm. and of olivine up to 4 mm. in length. It is slightly vesicular. Groundmass microlites of brown augite, of olivine-feldspar in lath shape, and magnetite. Larger augites are of a somewhat lighter shade, and show zonal structure between crossed nicols. Larger olivines are numerous, and very uniformly distributed. Fibrous isotropic patches occur which may be analcime. Beyond a few larger laths, the porphyritic feldspar is confined to one crystal in which a band of inclusions marks out a rhomb.

CASTLE ROCK.

Castle Rock is a mass of reddish breccia, and rises to a height of about 100 ft. above the general level of the Ridgeway. It gives one the impression of being the solidified pipe of a vanished volcano. Between the rock and the shore, but at a considerably lower altitude, were several small cones extending over an area something like 300 yards towards the ship. All the specimens taken came from one or other of these cones, and were obviously *in situ*, though taken from detached fragments.

Castle Rock, 1.—Dark-grey, minutely granular rock. Enstatite, brown mica, feldspar in broad laths and irregular patches, uniformly clouded. Camptonite. From small cone below Castle Rock, nearest to ship, *in situ.*

Castle Rock, 2.—Black basalt, in part highly vesicular, in part compact. No visible olivine. This rock, with Castle Rock, is typical of this area; both are from the same cone.

Castle Rock, 3.—Very dark-grey rock, slightly vesicular, with zeolitic amygdaloids, minutely crystalline texture. Groundmass, feldspar laths, minute pale-brown augite, olivine, and magnetite. Larger forms of olivine and augite, frequently with good outline. The zeolite filling the vesicles is

isotropic, probably analcime. Basalt. From small cone within 200 yards of Castle Rock, south of and below same.

Castle Rock, 1.—Black basalt. Prominent crystals of black augite and pale-green olivine. There is a sharply defined inclusion of granular augite and olivine, with no trace of any transitional material, between this and the basalt: greatest dimension of inclusion as shown in specimen, 45 mm. Another specimen shows an inclusion, equally well defined, which is practically all olivine, there being only one visible fragment of augite. A section of the augite-olivine inclusion shows coarse-grained olivine-augite rock with ophitic structure. The augite pale green with a shade of pink, non-pleochroic. The merest beginnings of schiller structure are visible in places. Below Castle Rock, nearest to the rock.

Second Knoll.

Black Vesicular Basalt.—This was one of the less-prominent landmarks, and consisted of a cone of angular lumps of black vesicular basalt of vitreous appearance. From this a ridge of snow extended northwards for some 200 or 300 yards. Whether this was a compacted drift ridge or merely a bank of basalt covered with snow it is impossible to say.

Termination Rock.

Termination Rock is officially known as Hutton Cliffs. The name was given by Mr. Hodgson for his own convenience, as the exposure was the most distant one from the ship, and therefore the last on the Ridgeway. No. 1 was taken from the base of the cliff, which is some 200 ft. high, and sheer.

Termination Rock, 1 (Hutton Cliffs).—Compact, olive-green mottled with black. Many of the black included fragments are obviously amygdaloidal, the vesicles being filled with white zeolite; spots of this mineral also occur in the green part. A volcanic agglomerate. Fragments of green, black, and brown glassy highly vesicular rocks, all of which contain olivine crystals. Some of the black fragments are amygdaloidal, the vesicles being filled with a dull dusty-looking substance of finely fibrous structure, white by reflected light. This same substance also occurs at intervals throughout the slide, between the constituent fragments. One or two small black patches show numerous lath-shaped feldspars. Brown augite is rare, and present in small forms only. The glass in this rock is now represented by alteration-products.

Apparently akin to the tuffs from "Bare Rocks" mentioned on page 110 of the official report.

Termination Rock, 2 (summit).—Some small specimens of black vesicular basalt.

Termination Rock, 3 (summit).—A dark-grey slabby rock, with slight green shade; shows a little tabular feldspar. Microlitic groundmass very ill-defined feldspars, small irregular prisms and pairs of very pale-green augite, sphene, magnetite. The larger constituents are feldspars, chiefly in elongated forms, but at places stouter; nearly all ill-bounded, and many so crowded with microlites that it is only between crossed nicols that they can be distinguished. There are a few augites slightly larger than the general run, but these are rendered practically opaque by minute magnetite. Trachyte.

SULTAN'S HEAD.

Sultan's Head, 1.—Olive-brown tuff, rather soft. A typical palagonite tuff; the grains are subangular, and a few present spheroidal structure. In places a vesicular form in the original material is evidenced. A little calcite here and there, and much colourless cementing-material, which is not quite isotropic. A variety of the basalt tuff from Sultan's Head described on page 109 of the official report.

Sultan's Head, 2.—Specimen showing passage of olive-brown tuff (Sultan's Head, 1) into volcanic agglomerate with this material as a base and considerable included fragments of dark basalts.

Sultan's Head, 3.—Small specimens of grey pumiceous rock. The interiors of the gas-cavities highly glazed. A highly vesicular rock, pale-grey base not quite isotropic. Fragments of both quartz and feldspar, the former with small fluid inclusions, none of the feldspar twinned. A little granular magnetite. Pumice. It is not certain that this occurs here *in situ*.

MOUNT EREBUS.

The base of this mountain to the west of the Ridgeway seemed to be composed almost entirely of kenyte. The larger exposures of Skuary Point, Cape Barne, and Cape Royds had other rocks in addition, the last-named with a copious sprinkling of blocks of granite. No. 1 specimen was taken from the sea ice immediately below a small exposure some few feet above sea-level, from which it had obviously fallen. This exposure was on the side of Mount Erebus, but only a few yards from the origin of the Ridgeway.

Erebus, 1.—Reddish-brown rock, compact base. Numerous tabular feldspars, water-white, with visible inclusions of groundmass. The planes of all these feldspars are approximately parallel, and thus on one surface they give lath-shaped sections, averaging about 12 mm. by 1·5 mm. The rock is also slaggy, and contains gas-cavities flattened and elongated parallel to the planes of the feldspars. While quite fresh it is thus very friable. The groundmass brown, apparently glassy, with brown and black dusty inclusions; contains numerous lath-shaped feldspars. In some cases these are invaded along the centre from either end by black dusty material, which shows somewhat elongated forms under high power. The larger crystals of anorthoclase contain numerous inclusions of groundmass, arranged in zonal fashion, and the crystals show between crossed nicols slight local differences of tint which mark out zones exactly corresponding to the inclusions. The olivine crystals are pale green, and usually accomplish clear crystal outline over rather more than one-half of their circumference, being invaded elsewhere by prolongation of the groundmass, severed inclusions of which are also common. Nepheline is rather prominent in some parts of the slides, and in one place is associated with an olivine crystal. Trachydolerite, akin to kenyte.

Erebus, 2.—A compact grey rock of close texture, with slight tendency to cleave in flakes. Numerous tabular feldspars, mainly but not entirely in parallel planes. These give lath-shaped sections up to 25 mm. in length, and are 2 mm. in breadth. A comparatively pale ground, considerably darkened, however, by fine granular magnetite. Much looks like a brown glass, but no part is actually isotropic. There are numerous small feldspar laths. The larger feldspars are striated with alternate narrow and wide bands; the largest show zonal structure between crossed nicols, and small

olivine inclusions as well as slight inclusions of groundmass. Some small and well-formed nepheline, occasionally with central inclusions of groundmass. Pink-brown augites; small forms are rare. A fair amount of olivine; small forms are again rare. Some large grains and crystals of magnetite. Two cracks in the rock have been recemented with a clear colourless mineral of very low double refraction. Trachydolerite. Specimen taken from the end of the jetty *in situ*.

Erebus, 3.—Coarse-grained granitic texture, with tendency to banded structure. The larger feldspars flesh-coloured, the smaller semi-opaque white. Quartz clear. Much black mica. Feldspar slightly clouded, but in places quite clear, practically all striated; all contains apatite. Patches of micro-pegmatite. There are large areas of quartz, which show fairly numerous fluid inclusions with bubbles. A fair amount of dark mica in brown and green shades. Quartz-diorite. From Cape Royds. not *in situ*.

Erebus, 4.—Felsitic texture: granular crystalline; general shade light indian-red; some feldspars, all quite small, are a brighter pink. Micro-pegmatite, with patches of clouded red feldspar in tesselated form, and other areas of clear colourless feldspar in similar form: striation not infrequent, but somewhat indistinct. One feldspar is clouded in centre, with clear outer zone, surrounded by micro-pegmatite. A somewhat similar case occurs where the centre is of a pale green-grey and polarizes differently from margin, although extinguishing with it. Hornblende in blades and irregular forms, olive-brown in parts but mainly green, is scattered rather sparsely through the slide. The larger grains of quartz are not prominent, and contain a few very small fluid inclusions with bubbles. From Cape Royds, not *in situ*.

These last two specimens are samples of the numerous blocks of granitic material which lie here and appear to present great variety.

Turtle Island.

Turtle Island was a small pyramidal islet some eight miles from the ship, and the object of rather frequent excursions. It is about a couple of hundred yards long and little more than half that in diameter, perhaps 60 ft. high. On its eastern side were considerable pressure-ridges on the sea ice. At the eastern base the rocks were compact, weathered to simulate stratification, and appeared to be the ordinary olivine basalts of the district, but here the olivine crystals were very large and conspicuous. The general surface of the islet consisted of very fine rubble, with occasional boulders of kenyte and other volcanic rocks, the crystals from which sparkled in the sun like diamonds, and were rendered conspicuous for a considerable distance.

Turtle Island, 1.—Two specimens, one with a black compact base and very elongated rhombs of feldspar, practically lath-shaped in cross-section; the other brown-black, rougher and more slaggy base, with well-developed rhombs of feldspar. The first shows parallel structure, the second does not. Trachydolerite and kenyte. These specimens were from boulders.

Turtle Island, 2.—Dark-grey, compact trachytic, with large vesicles, up to 13 mm. diameter. Cleaves easily in slabs of irregular form from 5 mm. to 10 mm. thick. Groundmass light purple-brown augite and plagioclase feldspar in wisps and rods, with a little olivine and considerable quantity of magnetite. The sole porphyritic constituent is feldspar in very irregular forms. Trachyte.

Turtle Island, 3.—Granular, somewhat friable, black and very light grey; in a fresher piece the light crystals are more amber-coloured. One specimen shows that this rock occurs as nodules in a black basalt of vesicular character. In some pieces the olivine and augite are clearly recognizable as such in the hand-specimens. There are small specimens in which olivine is present to the practical exclusion of all other minerals. Nodules from basalt.

Turtle Island, 5.—A very heavy black friable granular rock with iridescent play of colour on the grains represents apparently a nodule from basalt in which the augite is present to the practical exclusion of all other minerals. Rich-brown augite (pseudo-hypersthene) in large ophitic plates. No recognizable pleochroism. The cracks stained a very dark brown, almost black. Numerous inclusions, very dark brown, lying along two directions coincident with the cleavage. Many of these inclusions are mere rods, others are lath-shaped, some few are broader plates. They exhibit no pleochroism, and appear to be isotropic.

Turtle Island, 6.—A small weathered stone, grey and buff. Base apparently feldspar, colourless, giving aggregate polarization in low tints, and showing an occasional rod form. Granular magnetite scattered uniformly throughout the slide. There is much of a golden-brown mineral in platy and sometimes rough prismatic form, which is bright orange-yellow by reflected light, shows no pleochroism, fairly high double refraction, and straight extinction in sections approaching the rectangular: this occurs in very minute forms.

INACCESSIBLE ISLAND.

The outermost of the Dellbridge Islands, so called because it was difficult to make the ascent. The northern side consisted largely of black basalt, weathered to simulate stratification up to a height of nearly 20 ft. Near the western end was a large scree of very fine rubble. The rocks were much confused at the eastern end, where all the specimens were obtained, and apparently dipped to the south.

Inaccessible Island, 1.—Medium grey, trachytic texture. A very few visible augites. White spots of intersecting feldspar crystals, in many cases in small druses. Groundmass pale grey, consists of a felted mass of minute fibres, with some magnetite, largely in very minute forms, and numerous rather irregular prisms of very pale-green augite. Very numerous feldspar laths, rather stout in section, for the more part simply twinned. The symmetrical extinctions are $\pm$ 20°, which suggest andesine. The slide also shows glomero-porphyritic structure, with aggregates of twinned feldspar free from interstitial matter; in one of these aggregates occurs a crystal with very closely repeated twinning, but elsewhere all are simple twins. One larger porphyritic feldspar occurs, with numerous inclusions of augite and magnetite. An occasional pale-green porphyritic augite, some with good crystal form, some much rounded, yet others entirely clouded with magnetite. Augite-andesite.

Inaccessible Island, 2.—Yellowish-grey trachyte, minutely open-textured. A pale yellow-brown ground of varying depth of tint, of very feeble double refraction, and containing both magnetite and sphene in minute forms, with rarely a small grey-green prism microlite which is apparently augite. Numerous well-terminated feldspar laths, and some few rather larger and stouter forms. Around the larger of these the lath feldspars show flow

structure. The rock appears vesicular, with the vesicles sometimes completely, sometimes only partially, infilled with a zeolite, which is probably analcime. Many of these zeolitic areas have, however, the distinct appearance of being pseudomorphs after some previously existing mineral, and hexagonal sections for this latter are fairly clearly indicated here and there, with residual patches of unaltered mineral which may well be nepheline. The extremely small percentage of augite is noteworthy. Treatment of a section with HCl followed by fuchsin produces differential staining. The groundmass becomes bright red, the feldspars remain water-white, and the zeolite areas take a violet shade. It then becomes clear that these latter are in many cases very certainly replacements of a mineral of hexagonal form. The straining of the groundmass also throws into relief numerous thread-like feldspars of a smaller order than the lath shapes, which alone are clearly discernible in the unstained specimen. The HCl which has been in contact with this rock is stained with iron, and yields on evaporation deliquescent crystalloids with cubes of sodium-chloride. The other chlorides apparently include that of aluminium. Phonolitic trachyte (altered). Apparently official specimen 803.

Inaccessible Island, 3.—Purple-brown trachytic texture, rather compact. The ground a rich-brown glass, with some magnetite. Very numerous lath-shaped feldspars fairly well terminated, and frequently showing a line of inclusions of groundmass down the centre. There are also smaller much-attenuated feldspars. The laths as a whole have one general direction. Larger feldspars, rectangular and rhomboidal, occur; these are mainly associated in groups of two or three, in contact with each other and partly intergrown, and show considerable glass inclusions, but only in one case polysynthetic twinning. No nepheline or zeolite is discoverable, but the rock is in many respects much like Inaccessible Island, 2. Trachyte, probably phonolitic. Apparently official specimen 802.

Black Island.

The first camp here was pitched about the middle of the eastern side of the island, not far from where the party landed. The specimens Nos. 2 to 7, 9, 10, and 14 were all taken from a "rubble-heap" a few yards from the tent. This so-called heap was an area some 20 yards by 3 yards, and none of the specimens were *in situ*.

Black Island, 1.—Dioritic texture, dark brown and practically white crystals. Brown augite, ophitic, diallagic in parts. The margins frequently darkened, sometimes with the development of a rich-brown pleochroic mineral. A few crystals are partially altered to uralite. Much feldspar, apparently all labradorite. Considerable areas of micro-pegmatite, in which the feldspar is always clouded. A sprinkling of ilmenite and some apatite. Quartz-augite-diorite. From half-way up peak of island, not *in situ*.

Black Island, 2.—Coarse-grained granite, pink feldspars, apparently precisely like Erebus, 3.

Black Island, 3.—Very fine-grained pale-grey rock, slightly mottled. Much white mica in minute brightly sparkling form. Groundmass microfelsitic, with minute sericitic mica. A few scattered grains of magnetite. Scattered blades and grains of olive-green hornblende, some of which shows striking pleochroism from olive to vivid blue-green. The porphyritic constituents are patches of much-clouded white feldspar, and quartz in sharply

bounded grains, some of which have been cracked and then parted by considerable belts of groundmass. There appear to be no fluid inclusions. Quartz-felsite.

Black Island, 4.—Very pale-grey fine-grained sandstone, with marked banded structure, twelve bands in 7·5 mm. Rounded quartz-grains, with more rarely a fragment of feldspar. Inclusions of apatite, zircon, and dark mica occur in the quartz. There are also numerous fluid inclusions with bubbles, the inclusions large and the bubbles of very varied size. The cementing-material is silica.

Black Island, 5.—Fine-grained granular quartzite, breaks in thin slabs; colour red-brown. Well-rounded grains of quartz, with an occasional more angular feldspar; the latter in some instances is microcline. The red colouring-matter is confined to the outside of the grains. Mineral inclusions in the quartz are very rare. The fluid inclusions are not numerous, and are very small. To all appearance the materials of this quartzite are derived from a different source from that of Black Island, 4. The cementing silica is frequently, but not invariably, in crystal continuity with the adjacent quartz-grain.

Black Island, 6.—Purple-grey rock, breaks in thin slabs, very fine texture. Minute, very confused structure, even the feldspar laths being but rarely well defined. The larger feldspars are nearly all mere patches, without crystal outline. All are cracked and yellow-stained along cleavages. The mineral may be labradorite, but its determination is difficult. Small irregular prisms and grains of pale-green augite are very common, and occur not only in the groundmass, but also as inclusions in the feldspar. Some few larger augites are now almost entirely replaced by magnetite. There is a fair quantity of magnetite and somewhat more of granular sphene scattered throughout the slide. Camptonite.

Black Island, 7.—Very fresh-looking rock of somewhat minutely dioritic texture, dark grey with light grain. The groundmass an irregular coarse matwork of plagioclase, clouded slightly in places, but for the more part clear, the forms comparatively short, probably labradorite. There is some magnetite, chiefly associated with augite. Large plates of augite, almost entirely diallagic, in shades of olive-green. Augite-diorite (gabbro).

Black Island, 8.—A mottled rock in dark purple-brown and black. Weathered surface presents appearance of flow structure. Precisely similar rock found at first camp. A very fine-grained rock of confused nature. Consists apparently of ill-formed feldspar laths, small ill-formed prisms, and grains of pale-brown augite, magnetite, sphene, a little interstitial calcite, and an undetermined zeolite. The zeolite has too-high double refraction for analcime, and it with the calcite joins to form an irregular patch, around one end of which the feldspar laths are well defined and lie parallel to its margin. From half-way up North Peak, not *in situ*. Camptonite.

Black Island, 9.—Pink granular felsite, spotted with dark green. Porphyritic quartz and feldspar, but no well-formed crystals. Much micro-pegmatite, which is the prominent feature of the slide. Some of the feldspar is clouded, some striated. Practically all the quartz areas are in mosaic. There is a little green hornblende in grains and blades; the hornblende is to a great extent broken down to a dark-brown product, with the apparent production of some epidote. Hornblende micro-pegmatite.

Black Island, 10.—Black basaltic rock, with olivine freely developed. Groundmass holocrystalline, consists of lath-shaped feldspars, brown augite, olivine, magnetite, and sphene. Feldspar also occurs in larger form, with rounded outline, and showing between crossed nicols a few very narrow bands widely spaced. Olivine inclusions in this feldspar. A few larger forms of pale-brown augite with rounded outline. Frequent larger olivines mainly idiomorphic, but some with corroded outline. Trachydolerite.

Black Island, 11.—Weathered pebble. Rough-textured fine diorite in structure. Colour brownish-grey. Large plates of augite, in parts markedly diallagic. The more normal mineral has a distinct pleochroism from pale bluish-grey to pale pink. Here and there is slight decomposition, with development of serpentine. There is a very little brown mica, with strong pleochroism. Between the augite areas is a matwork of clear feldspars in moderately stout forms, apparently labradorite. Slight decomposition occurs here and there. Ilmenite and apatite are also present. Augite-diorite.

Black Island, 12.—Very light warm buff, with greener shades locally. Trachytic texture. Ill-bounded feldspars, mainly lath-shaped, but some of stouter section, in a groundmass of minute feldspar mosaic. A fair quantity of aegirine-augite, pleochroism yellow-brown-green to blue-olive-green, in small prismatic forms and grains, for the more part ill-bounded. Possibly a little apatite. Under the $\frac{1}{6}$-inch objective minute hexagonal and square forms of a clear mineral are visible. When the section is treated with hydrochloric acid, well washed, and stained with fuchsin it takes the dye locally where these hexagons and squares occur, and shows them marked out by the cleavage-cracks in larger forms of a mineral which is almost certainly nepheline. Phonolitic trachyte. From south-west corner of island; occurs *in situ*. This is 610 of official report, but there reported in error as from south-east of island.

Black Island, 13.—Volcanic agglomerate. Greenish base with black nodules, evidently basaltic. From north end of island. Described on page 139 of official report.

Black Island, 14.—Dark-grey rock, almost black. Tendency to conchoidal cleavage. Very close grain. Micro-crystalline quartz and reddish-brown mica are the prominent constituents. There is a distinctly parallel structure throughout the slide, but no banding. A fair amount of magnetite in irregular patches. An altered sedimentary rock from a contact zone. Apparently official specimen 525, page 135.

Black Island, 15.—Very dark-grey compact rock. Possibly a very little olivine. Groundmass microlitic. Consists of feldspar laths all conforming to one general direction, sphene, magnetite, and augite. In this occur larger water-clear feldspars, some striated, some zoned, many in associated intergrown crystals. A few porphyritic very pale-brown augites, and sphene in larger forms than in the general ground. From top of north peak of island, practically *in situ*.

Black Island, 16.—Slaggy vesicular lava, exterior with green tints, fracture red and black. Very closely resembles Brown Island, 4. From top of north peak of island, *in situ*.

Brown Island.

Brown Island, 1.—A very pale-grey slightly greenish trachyte. Compact and hard, weathered surface hard also. A few dark acicular crystals

visible; greatest observed length, 2·5 mm. A few glancing spots of feldspar can be seen. Groundmass is felted feldspar, with an occasional larger individual, rather ill defined (symmetrical extinctions appear in some instances to indicate anorthite). The ground is a very pale buff in colour, scarcely distinguishable as tinted, except by contrast with the larger colourless feldspars. There are fairly numerous small prismatic forms of aegirine, with an occasional larger crystal rendered practically opaque by magnetite. With the one-inch objective and careful lighting a clear mineral in very minute forms may be seen to be distributed throughout the slide; with the $\frac{1}{6}$-inch this is seen, in part at least, to possess hexagonal outline. On treatment with HCl followed by fuchsin the slide takes the dye locally, and thus indicates that the mineral last mentioned gelatinizes in the acid. The grains are then found to be parts of larger crystalline areas marked out by the cleavage-cracks therein. Identification as nepheline appears certain. This is the more probable since the acid which has been in contact with the slide yields, on evaporation, cubic crystals and aluminium-chlorides. There are some small porphyritic feldspars (the largest under 2 mm. in length), several of which show polysynthetic twinning, while the constituents of the groundmass frequently bend around them in flow form. Phonolytic trachyte. From crater. See official specimen 607, page 115, from which it differs slightly, especially in being hard and compact.

Brown Island, 2.—A black very compact rock, with augite and olivine visible here and there. The specimen is slaggy at one angle. A rock almost opaque, with granular magnetite. Fairly frequent lath-shaped feldspars, ragged at the ends, and showing closely repeated twinning. Brown augite, in small crystals, is by far the most prominent mineral in the groundmass; it shows no pleochroism. The magnetite inclusions in this mineral are comparatively few. The slide shows one larger augite, cracked across the centre, and parted by a belt of the groundmass. The two parts thus formed have each a central area of bright green and a complete border of pale brown. The positions of extinction of the green and brown differ by about 7°; neither is pleochroic. Olivine is common, both in larger and smaller forms. It sometimes achieves good crystal outline, and, although rather free from inclusions, intrusions of the groundmass do occur in it, as also do the largest and best-formed crystals of magnetite which the slide presents. Basalt. From summit of island, *in situ*.

Brown Island, 3.—Light yellowish-brown rock; hard, but of open texture; appears slaggy under hand-lens. Vesicular, a brown glassy base of very feeble aggregate polarization. Lath-shaped feldspars, from symmetrical extinctions probably oligoclase. Some of the larger forms show very closely repeated twinning, and also considerable inclusions of glass. Some are quite clear in the centre of their length, but crowded with granules and microliths toward either end, finally dying away into the groundmass. There is a little brown hornblende, and magnetite in small crystals and dust. At places the vesicles have a narrow lining of zeolite. Andesite. Near top of south peak of island, *in situ*.

Brown Island, 4.—Two specimens of slaggy vesicular basaltic lava, very open textured, the one a rich brown, the other largely yellow-green. The fracture of the green specimen is black.

4*a*.—Highly vesicular, a rich-brown glass, almost opaque, red by reflected light. Olivine the only porphyritic mineral, except for the presence of a single rod of feldspar.

4*b*.—Less highly vesicular, almost opaque, red in parts, in parts almost black by reflected light. Some feldspar rods scattered sparsely. Olivine freely developed, and some augite. Summit of island, *in situ*.

Armitage's Sledge Party, near New Harbour.

Medium grain, granitic texture, black mica, white feldspar. At one point within a little space four crystals of clear brown sphene, the largest 2·5 mm. by 1·25 mm. Biotite-mica, pleochroism pale olive-brown to very dark greens and browns. A little chlorite, developed at the expense of the mica. Quartz in coarse mosaic, fluid inclusions with small bubbles, some apparently empty cavities. Two classes of feldspar. The greater part orthoclase, but a fair proportion of plagioclase, probably oligoclase. Both are very fresh in patches, much altered here and there. The plagioclase twinning shows the occasional shear of a crystal, and also considerable bending. Some apatite. Biotite-granite. Collected on the western sledge journey of 1902 by Lieutenant Armitage.

Western Mountains.

This collection numbers upwards of a dozen specimens, the wasters of a larger collection of loose rocks picked up by Dr. Wilson when on a sledge journey with Lieutenant Armitage to the southern extremity of the foothills of the Western Mountains forming the northern shore of the outlet of the Koettlitz Glacier. This journey was undertaken in December, 1903.

Western Mountains, 1.—Mica-schist, much dark mica partially leached and iron-stained. A gneissic rock of clastic appearance. Both feldspars and quartz are in interlocked granules, and both appear distinctly fresh. The feldspar is often striated (symmetrical extinctions 20°), and frequently penetrated by, or includes, needles of apatite. The quartz seems free from fluid inclusions. A few crystals of rutile occur. There is much mica, the more part intensely pleochroic from very pale pinkish-brown to rich red-brown; associated with this is white non-pleochroic mica, which in certain areas occurs in tracts of long bent blades, streaming in a uniform direction, and associated with patches of quartz and feldspar mosaic of fine grain, within which again are small patches of brown mica, otherwise excluded from these portions of the slide. It is to the white mica so developed that the marked schistosity of the rock is due. The whole slide gives evidence that the rock has sustained an intense crush—so intense, indeed, that the quartz-feldspar mosaic is at places reduced to a mere aggregate of powdered material.

Western Mountains, 2.—A grey rock of rough texture. A few feldspars are visible, but a rather dull brown-grey mica is by far the most prominent constituent. Much biotite. Face-colours vary from pale cinnamon-brown, with an occasional olive shade, to rich tints of brown in basal sections. Comparatively small patches and blades of hornblende are fairly frequent. The pleochroism is from pale olive to deep blue-green. Very numerous grains and some larger much-altered crystals of augite, showing slight pleochroism from bluish-grey to pink-grey. Large patches of calcite. All in a general confused groundmass of high double refraction, with serpentinous products. There is also, apparently, some secondary feldspar in mosaic form, and some sphene after titaniferous iron-ore. Dioritic lamprophyre.

Western Mountains, 4.—A dark basaltic rock. Groundmass pale brown. Consists of small brown augites and lath-shaped feldspars, with numerous crystals of magnetite. Some of the augite shows enclosures along both cleavages, giving well-defined dark lines. More or less this feature occurs throughout the slide. Olivine is present in much larger forms, colourless, occasionally with fair crystal outline, with inclusions of magnetite and sometimes of the groundmass.

Western Mountains, 5.—A thin slab, apparently of grey micaceous slate. Section cut parallel to cleavage. Much pale-brown mica, which, being largely cut parallel to the base, affords a fairly uniform tint throughout the slide, and appears as if filling the rôle of a ground in which the other minerals are set. Exhibits moderate pleochroism, and in convergent light shows a slight separation of the cross into hyperbolae. Short prisms of tourmaline of pale-green colour are rather common, and are very uniformly distributed. There are numerous subangular granules of clear untwinned feldspar. Filling the interstices between the other constituents is a substance white by reflected light, mottled with palest green by transmitted light, showing crystal granular and fibrous structure with high tints between crossed nicols; the constituents are in much too minute form for identification. Dusty ferrite stains the slide in places, and magnetite is somewhat sparsely distributed throughout. Altered sedimentary.

Western Mountains, 6.—Soft brown rock, lighter in colour and softer after passing 9 mm. to 10 mm. from exterior. Glaciated. Contains rounded sand-grains. A bright brown tuff with rounded fragments of feldspar, some striated, and less-numerous olivine fragments. A few inclusions of white and black rock minutely speckled, and also of brown glassy rocks with feldspar laths. Tuff.

Western Mountains.—The collection also includes a fragment of kenyte; a granular felsite, apparently hornblendic; and some granites or diorites.

GRANITE HARBOUR.

Granite Harbour, 1.—Compact horny texture, dull-brown rock, evidently a felsite, with small pink porphyritic feldspars. Small dark spots (1 mm. largest) rather widely scattered. Mica in somewhat granular form. Groundmass minutely crypto-crystalline, pink in shade, strewn with green microlites (pleochroic from browner to bluer shades). The longer axes of these microlites lie in one general direction, and the mineral is almost certainly mica. A very rare grain of magnetite occurs. Porphyritic feldspars, some entirely clouded with red decomposition-products, others in parts quite clear and colourless with irregular streaks of cloudiness and a hatching of lines of same. The feldspars are clearly defined against the ground, and appear to be in large part microcline. Here and there the green mineral invades them in somewhat massive form, and it also fills cracks in the rock.

Granite Harbour, 2.—Fine-grained granitic texture, white feldspar, black mica, quartz slightly stained in places. Feldspars slightly clouded locally, practically all oligoclase. The quartz contains small fluid inclusions, with bubbles, and some empty cavities. Much brown mica; pleochroism pale straw to dark greenish-brown, almost black; gives practically uniaxial figure in convergent polarized light. Apatite prisms are frequent, in acicular form, the central parts much darkened by some dusty black substance, which lies mainly in a series of planes parallel to the base. Pale granular sphene, at times with a core of titanic iron-ore. Quartz-diorite.

Granite Harbour, 3.—Finer grain of "G.H., 2"; minerals apparently identical. The rock breaks in slab form, and the mica shows tendency to mark out a parallel structure.

Granite Harbour, 4.—The whole specimen is practically one mass of feldspar. No visible quartz. There is some dark mica partially leached and largely altered to chlorite, which occurs also lining a joint-face.

Granite Harbour, 5.—A grey rock, fine-grained admixture of dark greenish-grey crystals and dirty-white; the specimen is a thin slab. Grey-brown diallagic augite, ophitic, with very slight pleochroism. Between the augite plates, labradorite-feldspar in moderately stout forms, frequently zoned. Occasional patches of micro-pegmatite; no porphyritic quartz. Some ilmenite. Small widely separated spots of red-brown mica, associated with the augite. Quartz-augite-mica-diorite.

Note on Glacier-recession, by T. V. Hodgson.

A great deal has been said and written about the retreat of the ice from north to south, and the glaciers from low to the higher levels. This has been based upon the fact that the edge of the Great Ice Barrier is some miles further south than it was when seen by Ross in 1839–40.

The various sledge parties encountered many glaciers the extremities of which do not reach the sea, or even come within reasonable distance of it. One fact must impress the Antarctic explorer, and that is the thinness of the ice-sheet and the large proportion of exposed rock. The thickness of the ice on the inland plateau is purely conjectural, and with the appliances of the average sledge party it would be impossible to measure it. Theoretical calculations have shown that ice cannot exist at a greater thickness than 3,000 ft., and one feels—for one can do nothing else—when in those regions that there is no reason to believe that it might possibly be more than this.

I would ask, what right have we to accept so readily the assumption that the temperature-conditions are becoming less severe, and that therefore the ice-cap is receding? It appears to me that the evidence is very weak at the best.

To begin with the Barrier, the amount of recession is small compared to its enormous area. It is greatest on the eastern side, where we have absolutely no knowledge whatever as to the source of supply. As compared to the mountains of the west, King Edward VII Land, from the little that has been seen of it, is low-lying country, and if such should ultimately prove to be the case it may also prove to be the larger feeding-ground.

Only in one spot has the rate of movement of the Barrier been measured. It was a rather crude measurement on a sledge journey near Minna Bluff, and is probably only local; it works out roughly at about a quarter of a mile a year. There is no evidence whatever as to the seasonal fluctuations of this ice-sheet: a series of mild or of severe seasons seems to me to be amply sufficient to account for the difference in the position of its northern face. The icebergs met with by the "Discovery" were for the most part very small, and I think I am right in saying that none of them were over three miles long.

As to glaciers, many of them do not come down to sea-level, but end abruptly, frequently at some considerable distance from it, and it is very much open to question if they have ever been anywhere near sea-level.

These facts have been interpreted as proof positive that the glaciation of the region is receding, it being regarded as certain that in no very far distant

period in such a climate all these glaciers did come down to sea-level, and that those that do so now were formerly of far greater extent. This, I think, is far too hasty a conclusion, especially when we consider that McMurdo Sound has never previously been visited by man, and very little is known of the entire region from the point of view of its physiographical conditions. Some of the so-called glaciers, like that in McMurdo Sound described in the present paper, the Drygalski ice-sheet, and probably others, require more detailed examination before any really definite and satisfactory opinion can be pronounced.

Within forty miles of our winter quarters were no less than three active volcanoes, one smoking vigorously, the other two quiescent, and in such a volcanic district it is only fair to ask what would be the probable effect of—(1) volcanic eruption, (2) earthquake.

First with regard to volcanic eruption. For how long would the trace of such an occurrence be perceptible except by actual and close examination of the ground? Apparently not more than a few weeks. Lava-flows certainly might be conspicuous for a much longer period; but their age and finer characters are not to be detected at distances measured by the mile. Ashes and other volcanic ejecta might cover large areas, and under some conditions, such as seen in the Brown Island rubble-mass, would absorb the sun's heat and quickly effect considerable changes in the subjacent snow and ice. Under other conditions the snow might speedily and effectively hide all traces of any eruption as visible from a distance.

In the matter of earthquakes, their effect might be far more serious, and at the same time even less conspicuous. It is by no means inconceivable that the land in the vicinity of McMurdo Sound has undergone some change of level quite recently from a geological point of view. How could it be recognized on a first visit? Further, what would be the effect of a "good average" earthquake on the sea ice in such a region? It would certainly mean considerable rupture, with probably a serious effect on the adjacent shores. From such a sheet at the Great Ice Barrier it is quite reasonable to suppose that a single earthquake of any magnitude would make such a difference to that sheet as would take many years to replace.

The land visited has been seen for the first time, and we have to take it as it stands. To assume its permanency during, say, the last thousand years seems to me to be putting a great deal into a first visit. Had we been able to stay four or five years, or to make an exhaustive survey of the Sound and its shores, we might have been in a different position. Before we talk so emphatically about the recession of glaciation on such limited experience it would be well to bear in mind the possibilities of volcanic energy.

Art. XLIV.—*The Post-tertiary Geological History of the Ohau River and of the Adjacent Coastal Plain, Horowhenua County, North Island.*

By George Leslie Adkin.

[*Read before the Wellington Philosophical Society, 5th October, 1910.*]

Plates XV–XIX.

The principal waterway of the central portion of the Horowhenua County is the Ohau River, situated between the Manawatu on the northern boundary of the former, and the Otaki and Waikanae in the south. Though a small stream, with a length of only twenty miles, its valley and the adjacent country present many features of great scientific interest. The total extent of its drainage area is sixty-four square miles, forty square miles of which is mountainous, the remainder being that portion of the adjacent coastal plain which is drained by the Ohau. Its largest tributaries are the Makahika and Makaretu Streams; others—viz., the Blackwater, Kuku, &c.—though inferior in volume, are by no means inconsiderable. At the point where the Ohau River crosses it the present coastal plain has a width of nine miles, but it is wider toward the north, and narrower in the south.

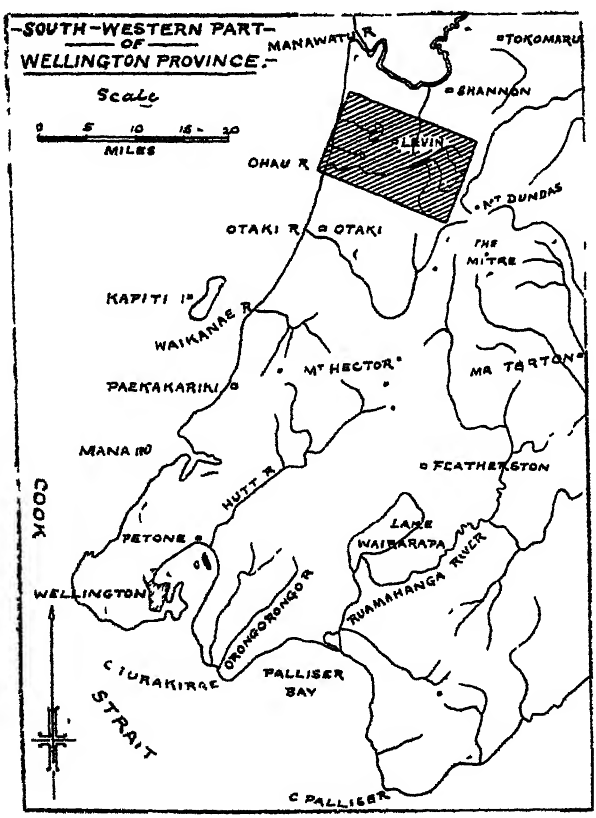
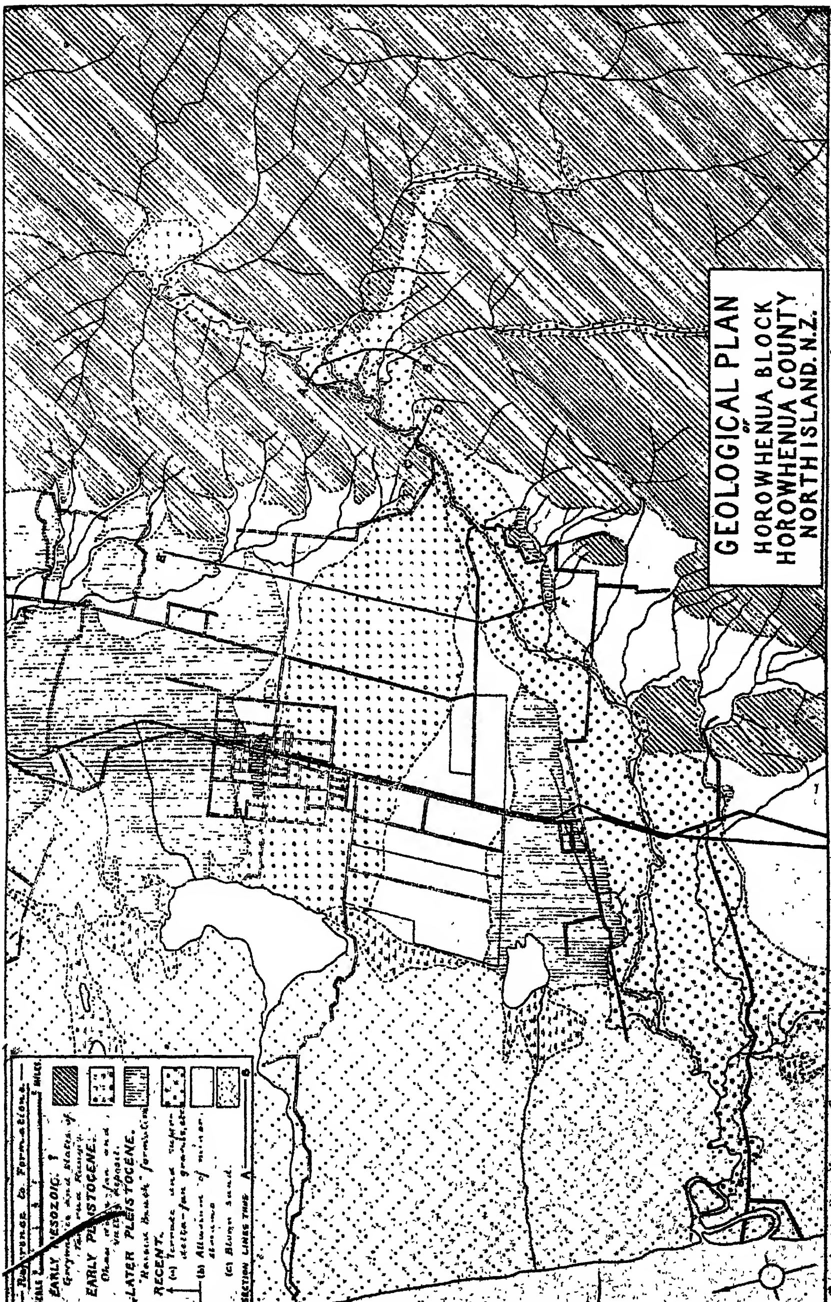


Fig. 1.—Locality Plan of Area described and mapped.

The Upper Ohau River, flowing in a valley which is alternately longitudinal and diaclinal, lies among the western subsidiary ridges of the Tararua Ranges. In this vicinity these latter constitute a wild stretch of country varying in altitude from 500 ft. to over 5,000 ft., and characterized by parallel tectonic ridges, and, in the diaclinal valleys, by tortuous rock-


GEOLOGICAL PLAN
OF
HOROWHENUA BLOCK
HOROWHENUA COUNTY
NORTH ISLAND. N.Z.
EARLY MESOZOIC.
EARLY PLEISTOCENE.
LATER PLEISTOCENE.
RECENT.
SECTION LINES THUS

THE OHAU VALLEY AND THE ARAPAEPAE RANGE

The lateral spurs truncated by the Ohau River and its tributaries

bound gorges. Here may be seen on a very extensive scale the effects of fluviatile erosion. The parallel ridges have been dissected, and their corresponding valleys deepened to an enormous extent by the action of high-grade streams and swiftly flowing rivers.

The culminating peaks of the district are the Mitre, 5,154 ft.; Mount Dundas, 4,944 ft.; and Mount Crawford, 4,795 ft. These are not within or even contiguous to the Ohau catchment-area, but lie near enough to intercept the moisture-laden westerly winds, and thus increase the rainfall within that area. The principal salients of the Ohau water-parting are Mounts Waiopehu, 3,588 ft., and Tawirikohukohu, 3,455 ft. It is near the summit of the latter that the Ohau River proper has its source.

In character the valleys of the Ohau and its two main tributaries differ considerably. As already stated, the Upper Ohau occupies a valley which is alternately longitudinal and diaclinal; the lower portion of the Makahika appears to flow in a deeply incised anticlinal valley, while that of the Makaretu, though diaclinal immediately above its junction with the Ohau, is for the most part longitudinal.

Prior to its occupation by European settlers most of the Horowhenua County was clothed in tangled virgin forest. The zone of heavy mixed bush (almost entirely beech near its upper limits) extends from low altitudes up to the 2,500 ft. contour-line. Above this elevation the bush usually becomes stunted, and is partially—or more often wholly—replaced by shrubs, forming a dense subalpine scrub. In most places at the altitude of 3,000 ft. the scrub terminates more or less abruptly, and the alpine meadow land is reached. The principal components of the latter are tussock-grass, *Astelia*, and alpine flowering-plants, while the subalpine scrub is for the most part *Olearia Colensoi* and *Dracophyllums*.

Though the district under consideration presents many features of interest to the botanist and the nature-lover, it is for the geologist that it reserves its chief attractions. The successive events within its limits have been so varied, and in some cases the action of the several natural agents so complex, that an examination of these events and operations should prove of interest to geological students.

Owing to the entire absence, or perhaps non-discovery, of fossil remains in the area under notice, the age of each of the geological formations described in the following has been determined entirely by stratigraphical considerations. Judging, however, from the views held by writers on the Tertiary and post-Tertiary geological history of New Zealand, the recent maximum elevation of the country occurred in the early Pleistocene, and it is upon this conclusion that the chronological divisions in the following are based.

At the close of the Tertiary epoch a plain of the Upper Tertiary, most probably Pliocene, strata was uplifted, and at the cessation of its emergence extended seaward on the western coast of the Wellington Province from the foothills of the Ruahine and Tararua Ranges to far beyond the limits of the present shore. At the termination of this uplift the elevation of our Islands was much greater than now, but, as the movement was more pronounced in the South Island than in the North, the latter Island did not experience so severe a "glacial period" as did the former. The Pliocene (?) plain is now not visible in this district, more recent deposits having completely covered it, and on this account its exact nature cannot be ascertained from observations made in this locality alone, but that the uppermost Tertiary strata had a comparatively plane and gently sloping

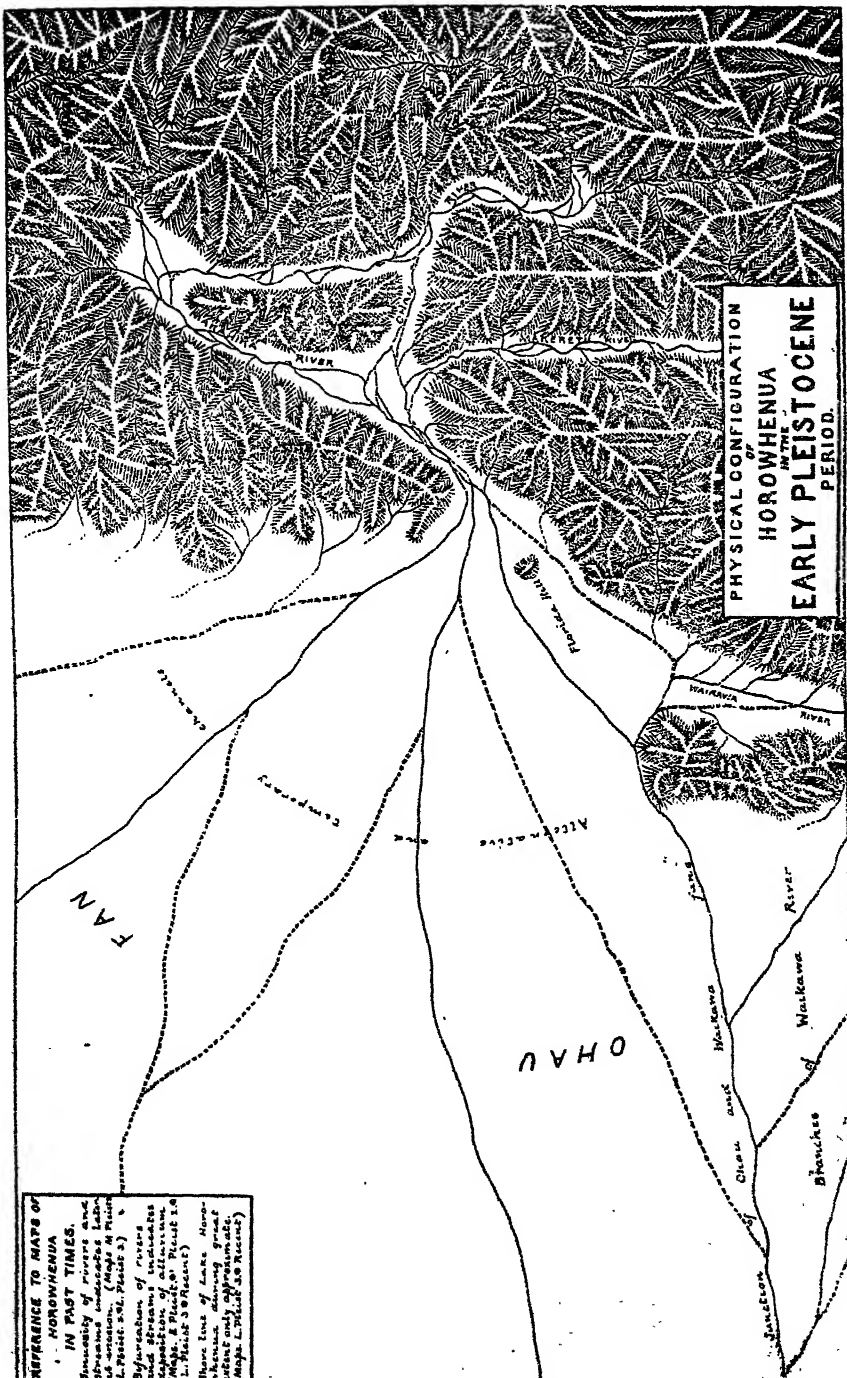
upper surface is inferred from the configuration and character of the superimposed fluviatile deposit about to be described.

The rivers which at present flow into the sea along the Terawhiti-Egmont coast-line had to traverse the newly uplifted plain, and were then not only of considerable length, but were also of greater volume, due to the greater elevation of the land producing a more abundant rainfall, and incidentally —for the fact does not affect the following considerations—a larger drainage-area. Like the others, the Ohau River crossed the Pliocene plain, and its subsequent history may be traced as follows: Upon leaving its vent in the foothills of the Tararua Ranges the Ohau River began to deposit material upon the Pliocene plain as soon as it was uplifted above sea-level. The deposited material took the form of a fan, and—for a while at least—kept pace with the uplift of the plain, as well as reducing the dissimilar gradients of the river-bed to a more uniform slope. The extent of the fan in a direction radial to its apex or summit is as yet unknown, but it certainly exceeds fifteen miles. Its maximum thickness is also not known, but in this respect it has been found to exceed 700 ft. At the present time the apex of the fan is only 345 ft. above sea-level, the average surface-slope being about 65 ft. in the mile, though the dip of its component layers at some depth below its surface is doubtless greater.

The bulk of this massive and coarse fluviatile deposit consists of somewhat irregular alternations of shingle, gravel, boulders, coarse sand (quicksand when saturated with water at some depth below the surface), and thin bands of clay. The beds of finer detritus are sometimes found in immediate association with the coarser material, any portion of the whole forming an exact counterpart of what may be seen on the Ohau River bed at the present day. The thin layers of clay which were deposited on many successive levels point to a temporary cessation of deposition on such areas, due to the river changing its course to a more or less distant portion of its fan.* During its formation the Ohau fan, with its great wastes of bare shingle stretching far and wide, must have presented a very desolate appearance. Any vegetation which managed to take root upon its barren slopes would, by the river changing its course, as was its unceasing habit, be completely covered by a stony mass. Swamps appear to have existed in hollows on the surface of the fan, probably on many successive levels, an ancient swampy layer 5 ft. in thickness having been met with at a depth of 323 ft. when the first trial artesian bore was sunk on the State farm at Weraroa. Another old land-surface was discovered when a well was dug on Section 38 in the Horowhenua Village Settlement. After passing through from 70 ft. to 80 ft. of gravel and shingle the workmen came upon a swampy layer 1 ft. thick, on the surface of which was found an entire pukatea stump *in situ*.

Driftwood has also been found at various depths in the Ohau fan. After heavy rains, driftwood derived from the bush-clad ranges and washed down by the swollen river would be cast ashore along its margin, and subsequently buried. In several cases when wells have been sunk into the fan this old water-borne timber has been brought to light. Twigs, leaves, and branches were found at a depth of 20 ft. in a well sunk in the Levin Borough about ten years ago. In another well a layer of branches and twigs and also a piece of pukatea timber were found at a good depth. In

* In the artesian wells sunk on the Weraroa State Farm the thin clay-seams were of very frequent occurrence.


PHYSICAL CONFIGURATION OF HOROWHENUA IN THE EARLY PLEISTOCENE PERIOD.
REFERENCE TO MAPS OF HOROWHENUA IN PAST TIMES.
OHAU
FAN
Florida Hill
WAIKAWA
RIVER
Waikawa River
Ohau and Waikawa
Junction of Ohau and Waikawa Branches

the third trial artesian bore on the State farm at Weraroa a rata log 2 ft. in diameter was found 135 ft. below the present surface. An old well-sinker stated that he had found flax-leaves which still retained their green colour beneath 18 ft. of shingle. This well was situated on Section 46 in Levin Borough.

From its apex to about two miles down its slope the Ohau fan has a fairly regular surface—that is to say, the curve exhibited by a cross-section would be a regular one. Further down its slope, however, its surface is characterized by ridges and hollows, whose strike is parallel to the dip of that surface. In this part the surface-curve, as shown by a cross-section would be sinuous, though here the fan still retains its hyperbolic contour. The ridges are usually from 5 to 10 chains apart, and, though they seldom have an amplitude exceeding 3 ft., are especially noticeable where a road crosses some of them.

As shown by the coarseness of some of the transported material, and also by the occurrence of driftwood, the Ohau fan is largely a flood deposit. As material was swept out from the mountain-enclosed valley on to the coastal plain, the river, being more confined to the immediate neighbourhood of its vent, would at first spread that material evenly in every direction. Further out, where spurs were absent and the river had freer play, ridges of deposit would be built up, until it was forced to change its course. While the river was in this state of oscillation—building up, being deflected when its bed became unstable, and eventually returning to its original position, and repeating the process on different parts of its fan—a slight change in the direction of its flow when near the apex of the fan would usually cause a considerable alteration in the position of that portion of its course situated further down the slope, and as a result the low radiating ridges would there be built up.

The Ohau River not only deposited shingle and gravel on the Pliocene coastal plain, but it also filled up with the same materials the deep valley it had cut (in the Tertiary epoch) through the rocks of the Tararua Ranges. This deposition of shingle, &c., in the primary valley of the Ohau was simultaneous with the formation of the fan, the latter being the downward extension of the former.

When the deposit in the valley had attained its maximum thickness it formed a sloping plain bounded by the hills, and traversed by the Ohau River and its two principal tributaries—the Makahika and the Makaretu. Formerly both these tributary streams joined the main river further up-stream than they do at the present time; also, the Ohau itself flowed across the shingle plain south-east of, though more or less parallel to, its present channel.

In shape the hill-enclosed alluvial plain which occupied the Ohau Valley bore a close resemblance to a three-fingered hand. The wrist was represented by the narrow strip, varying from 10 to 15 chains in width and three-quarters of a mile in length, which extended up-stream from the fluviatile vent; the palm of the hand was the widest part of the plain, lying round about the junction of the Ohau and its tributaries; and the fingers were the upward extensions of the shingle-beds in the respective valleys of these rivers.

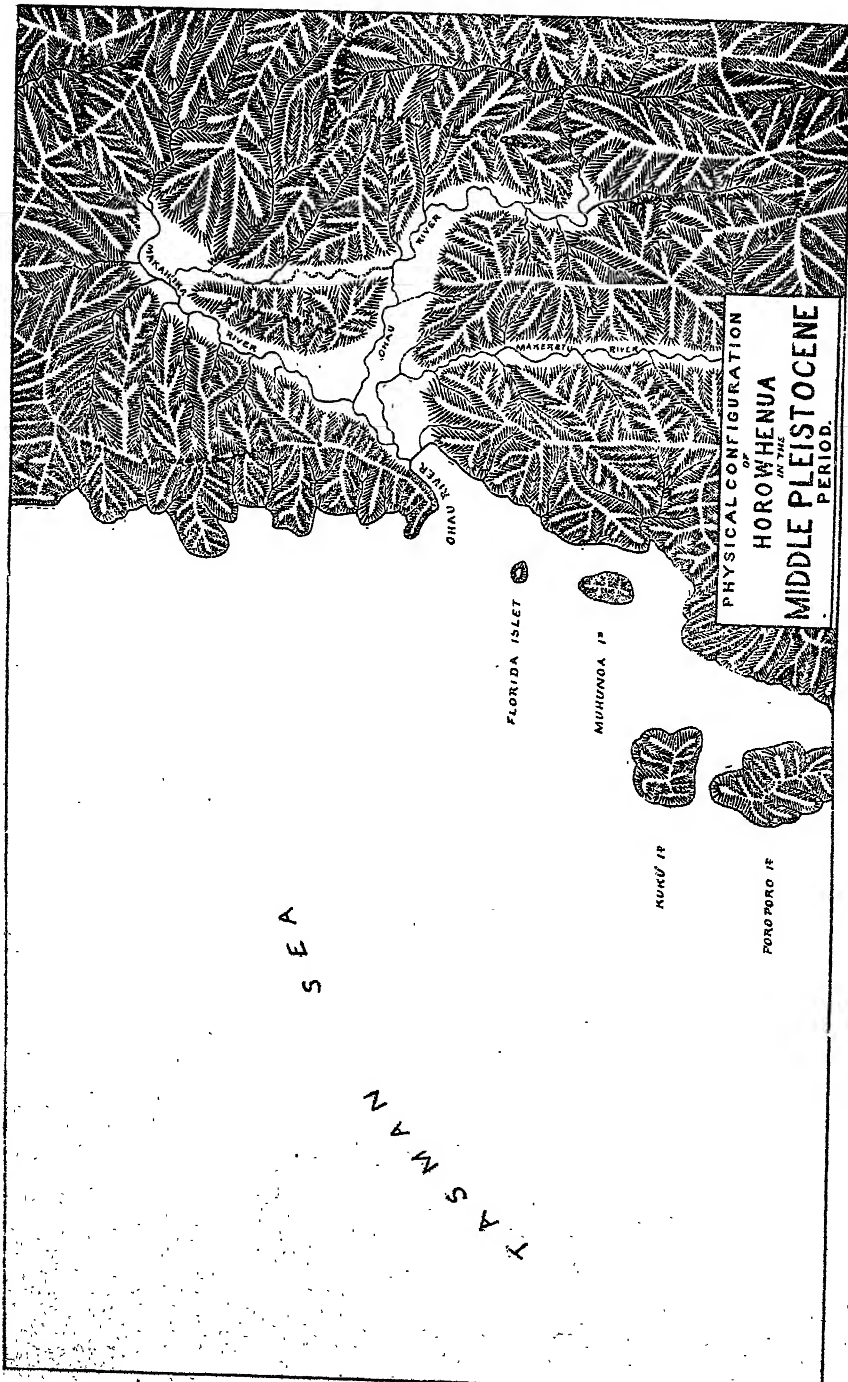
While the "valley plain"—that is, the plain within the hill-enclosed part of the Ohau Valley—was approaching completion the Ohau River appears not only to have debouched upon the "plain" just south of its present channel, but also to have had an alternate course, from its upper

gorges, between the Mill and Square Knob Ranges, to the present junction of the Makahika and Wai-iti Rivers, and from thence, in combination with those streams, down the Makahika Valley. Owing to the ruggedness of the locality and to its covering of dense bush, the exact nature and limits of this old suspected course have not been ascertained, but it is probable that it was similar in character to the branch of the "valley plain" which formerly occupied the Lower Makahika Valley. The position of this suspected course has been shown in the maps of Horowhenua in the early and middle Pleistocene periods, but has not been included in the accompanying geological map.

After the Ohau River had graded its bed and built up the surface of its fan and "valley plain" until it had attained its maximum altitude it deposited upon the upward extensions and the widest portion of the latter a superficial layer of clay varying from 10 ft. to 30 ft. in thickness. The precipitation of such fine sediment as clay alluvium was an indubitable indication that the cycle of deposition on the part of the Ohau River was coming to a close, and that very soon it would be flowing at grade—probably for the first time in its existence.

TABLE SHOWING THE SUPERFICIAL DIP OF THE "VALLEY PLAIN" AND OF THE FAN OF THE OHAU RIVER.

Reference to Topographical Map, page 517.	Datum-points.	Altitudes of the Datum-points.	Distances between the Datum-points.	Superficial Dip in Feet per Mile.
		Ft.	Ch.	
A ..	From the upper part of the "valley plain" (near the junction of the Makahika and Wai-iti Rivers)	777	164	95·12
B ..	To the middle part of the "valley plain" (near the junction of the Makahika and Ohau Rivers)	582		
B ..	From the middle part of the "valley plain" (near the junction of the Makahika and the Ohau River)	582	105	163·80
C ..	To the lower part of the "valley plain" (near the head of the Levin water-races)	367		
C ..	From the lower part of the "valley plain" (near the head of the Levin water-races)	367	43	40·93
D ..	To the apex of the Ohau fan	345		
D ..	From the apex of the Ohau fan	345	110	69·09
E .	To the line of the geological section across the Ohau fan	250		
E ..	From the line of the geological section across the Ohau fan	250	64	81·25
F ..	To the Arapaepae Road	185		
F ..	From the Arapaepae Road	185	90	58·6̇
G ..	To Levin Railway-station	119		
G ..	From Levin Railway-station	119	51	64·31
H ..	To Tirotiro Road (south end)	78		
H ..	From Tirotiro Road (south end)	78	66	50·9̇
I ..	To edge of Lake Horowhenua	36		


PHYSICAL CONFIGURATION OF HOROWHENUA IN THE MIDDLE PLEISTOCENE PERIOD.
OHAU RIVER
MAKERETU RIVER
RIVER
OHAU RIVER
FLORIDA ISLET
MUHUNOA Id
KUKU Id
POROPORO Id
TASMAN SEA

When the deposition of the clay alluvium had ceased—the rivers having attained a state of equilibrium—lateral erosion came into play, and the Ohau River began to cut into the southern end of the Mill Range at the point where it flows from its upper gorges on to the sloping "valley plain." The river cut away and removed about 20 chains from the end of this range, reducing its constituent rocks to the level of the valley deposit. It was at this time that the Arapaepae Range was shorn of the spurs on its eastern flank.* For the most part these spurs were merely truncated, but in the narrow part of the Ohau Valley, near the fluviatile vent, they were entirely removed. This partial destruction of the Arapaepae Range was the joint work of the Ohau and its two main tributaries, but in the Makahika Valley it was accomplished by that river alone, though, as will be shown later, in a remoter period. As a result of the lateral erosion the area of plain within the Ohau Valley was very considerably increased, and thenceforth consisted partly of the fluviatile deposit, and partly of equally elevated and graded platforms of the country rock. The spurs of the range lying between the Makaretu Valley and the fluviatile vent have also suffered truncation, but in this instance the operation must have occurred either during the excavation of the primary valley of the Ohau River or not later than the period in which the "valley plain" and fan were built up.

As shown by the annexed table, the average superficial dip of the Ohau "valley plain" was much steeper than that of its fan, the dip of the former averaging 110·76 ft. and the latter 64·88 ft. per mile. Though this is so, the progressive diminution of the slope between the upper limits of the "plain" and the lower part of the fan is not regular, but is characterized by declivities of varying steepness. The dissimilar gradients of the "valley plain" are, of course, due to the respective width and narrowness of the valley itself. The gentler surface-slope of the "plain" in the Lower Makahika Valley and in the narrow connection immediately above the apex of the fan (see table) shows that in these places the deposit exactly corresponds to those which sometimes form in valleys of uniform width; but where the Ohau Valley widens out (round about the junction of the Makahika and Makaretu Rivers) the contained deposit endeavoured to assume a fanlike structure, and there the surface-slope is much steeper.

The dissimilar gradients of the fan seem to have been produced in another fashion. They lead one to suspect that the final additions of material to the fan differed in character from the main mass of that formation. In building up its fan the Ohau River transported detritus to positions progressively more distant to the apex of the former. This had the effect of not only raising the surface of the fan, but also of extending its outer edges upon the surface of the Pliocene plain. As the fan approached completion the river's power of transportation diminished, the area of the fan ceased to be extended, and the final additions to its mass were deposited nearer and nearer the fluviatile vent. The alternate steeper slopes of the surface of the fan are the respective limits of detritus laid down in periods of transportation of lessening intensity.

* The truncated ends of the spurs closely resemble fault scarps, and might easily be mistaken for such. There is, however, no direct or exclusive evidence for such an origin, and fluviatile lateral erosion is a most satisfactory explanation. The origin of the truncation of the spurs is, for the most part, closely connected with the early Pleistocene fluviatile deposits.

When the river had reduced its bed to an easy grade, and had wandered over its completed fan and valley deposit, changing its course perhaps for centuries, the country began to sink. This subsidence affected the whole of New Zealand (which was immediately prior to this depression, of continental dimensions), and, by reducing the elevation of the country, put an end to any permanent snowfields or glaciers which may have existed in this part of the North Island during the "glacial period." In the North Island this reduction of elevation certainly amounted to more than 500 ft., the base of the Ohau fan deposits being fully that depth below the present sea-level. If during the period of great elevation Cook Strait was occupied by a river, the Ohau must have been one of its tributaries, and the inclined Pliocene plain over which it flowed the side of the old Cook Strait River valley. As Cook Strait is at its southern end (where the mouth of the lost river probably lay) considerably over 100 fathoms in depth, it would seem that an uplift of 1,000 ft. would be necessary to restore it to its original form—*i.e.*, an open and spacious valley. It is therefore safe to assume that the elevation of the southern part of the North Island was reduced by *at least* 1,000 ft.

The downward movement of the land was not sudden or convulsive, but slow, gradual, and perhaps imperceptible. The sea began to inundate the western border of the Pliocene plain, and in the course of time washed the edge of the Ohau fan. The subsidence continuing, the exposed area of the fan became less and less, until it was finally covered and the sea had advanced a little way up the Ohau Valley. The subsidence then ceased. The usual marginal deposits of sand were laid down against the western flanks of the Tararua foothills, marking the limits of the waves, mud and the finer material being deposited in deeper water at some distance from the shore.

In those days four small islands—Florida Islet, and Muhunoa, Kuku, and Poroporo Islands—lay off the coast of Horowhenua. Their approximate areas were 20, 70, 260, and 670 acres respectively. Their former insularity is shown by the presence upon their flanks of fragmentary patches of uplifted sea-beach deposits. On Florida Islet the latter has been best preserved, and is now elevated 360 ft. above sea-level. At the present time the former islands exist as isolated hills of the ancient rocks of the district. In the early Pleistocene, Florida Islet appears to have projected through the Ohau fan in a manner exactly like the isolated hills of the Upper Canterbury Plain.

A period of repose was followed by one of elevation, a movement which probably continues at the present day. The land rose with the same slow gradual motion as it had previously sunk. This elevation, however, differed from the previous subsidence in that it was local, the uplifted sea margin lying between Paekakariki and Wanganui. The sea receded and the sandy beach widened, so that in the course of time it formed a plain of marine deposit sloping toward the sea.

At that time the Ohau River flowed in a north-westerly direction across the newly uplifted coastal plain. It flowed in a wide, shallow valley between banks of the soft marine sandstone, and had for its bed the surface of its old fan. After cutting away the soft sandstone, the river formed in the surface of the fan a large number of shallow channels, varying from 1 ft. to 5 ft. in depth, and averaging 1 chain in width. These channels wind about a good deal, but their general trend is to the north-west.

Ohau River, near the Makahika Junction, showing the Convexity of its Bed.

Raised Beach near Shannon, seen from the Tararua Foothills.

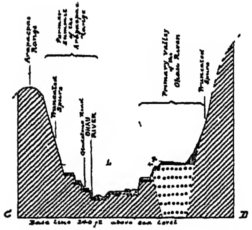
It is now much dissected by small streams and rivers.

Face p. 304.]

SOUTHERN END OF THE COASTAL PLAIN OF RAISED BEACHES, SEEN FROM PAEKAKARIKI.

The cliffs which border the sea further south can be seen running inland as a result of the uplift. The dunes of blown sand have completely covered the raised beaches in this locality.

GEOLOGICAL SECTION C–D OF THE OHAU VALLEY
40 CHAINS ABOVE APEX OF FAN



— SCALES —

CHAINS 0 10 20 30 40 CHAINS

FEET 0 100 200 300 400 FEET

— REFERENCE. —

SECTION A–B

1 Fragment of valley plain not on line of section
2 Probable spur projecting on to "valley plain"
3 Higher terrace not on line of section

SECTION C–D

1 Level of lateral erosion of Arapaepae Range
2 Surface of super fan gravel

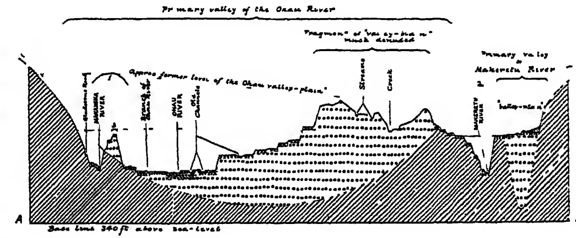
SECTION E–F

1 Surface of super-fan gravel
2 Surface line of Ohau fan
3 Floor of valley cut in R.B. sandstone by Ohau R.

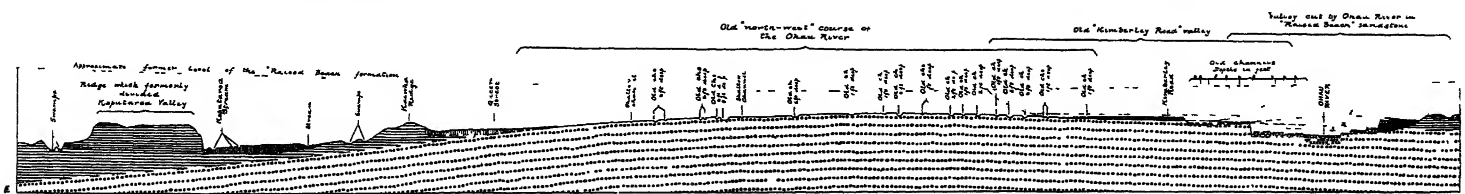
— REFERENCE TO FORMATIONS —

— AGE —	— FORMATIONS —
EARLY MESOZOIC ?	Graywackes and slates of Tararua Ranges
EARLY PLEISTOCENE	Older gravels etc of Ohau R. fan and valley deposit
LATER PLEISTOCENE	"Raised Beach" formation
RECENT	Newer gravels etc of the Ohau River: Terrace gravels
RECENT	Newer gravels etc of the Ohau River: Super-fan gravels
LATER PLEISTOCENE RECENT	Alluvium of minor streams (flood-plains etc)

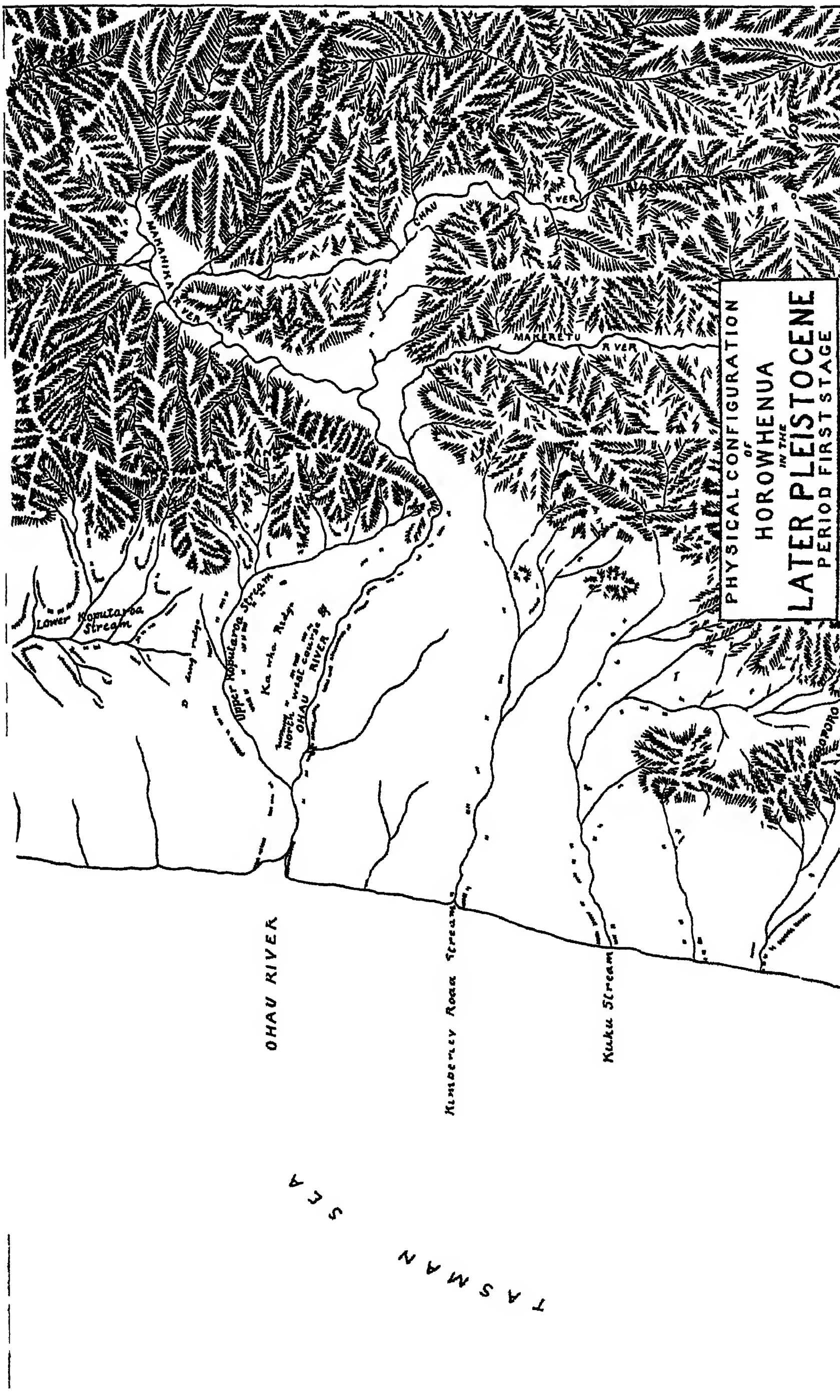
GEOLOGICAL SECTION A–B OF THE OHAU MAKAHIKA, AND MAKERETU VALLEYS
150 CHAINS ABOVE APEX OF FAN



GEOLOGICAL TRANSVERSE SECTION E–F OF THE OHAU FAN, THE OHAU VALLEY, AND OF THE SUPERINCUMBENT "RAISED BEACH" FORMATION
115 CHAINS BELOW APEX OF FAN



Surveyed and drawn by G. L. Adkin


PHYSICAL CONFIGURATION
OF
HOROWHENUA
IN THE
LATER PLEISTOCENE
PERIOD FIRST STAGE
MAKERETU RIVER
OHAU RIVER
Kimberley Road Stream
Kuku Stream
TASMAN SEA

This old "north-west" course is what may be termed the "intermediate stage" in the recent geological history of the Ohau River. Formerly by the process of aggradation it formed a massive deposit of shingle and gravel, and now by erosion it has excavated a deep valley in that formation. It is hardly likely that these very adverse conditions were abruptly consecutive, but that they were separated by an intermediate stage, which was a period when the river was neither depositing material nor to any great extent scooping out a well-defined channel. The old "north-west" channel was this "intermediate stage."

Though the shallow "north-west" valley of the Ohau River eventually attained a width of about a mile and three-quarters, it was at first much narrower. For a reason which will transpire in the sequel, the river—which originally flowed to the sea near and parallel to the present position of Queen Street (Town of Levin)—continually attacked its left bank, causing it to retreat to the vicinity of Kimberley Road. Prior to this lateral erosion by the Ohau River, the streams from the hills a couple of miles south of the fluviatile vent combined and occupied a wide but shallow valley situated along the line of the present Kimberley Road. The stream formed by this union flowed first into the sea, but afterwards into the southern end of Lake Horowhenua, which was then from 30 ft. to 40 ft. deeper (and consequently more extensive) than now: and when it had excavated its valley through the sandstone formation to the upper surface of the Ohau fan it filled its valley-bottom with alluvium—clay derived from the hills at its sources. By the lateral erosion just described the Ohau River removed the right bank of the "Kimberley Road" valley, tapping it and cutting into the clay alluvium. Though subsequent erosion has removed some of this clay deposit, the remainder can still be seen extending from the intersection of the Arapaepae and Kimberley Roads, through the Weraroa State Farm, toward the southern end of Lake Horowhenua. Originating as a flood-plain, it constitutes one of the most fertile portions of the district.

By the time the Ohau had gained access to the old "Kimberley Road" valley, however, the latter had been deserted by the stream which formed it. The "Kimberley Road" stream seems to have been divided from the streams which drained the hills still further south by a low ridge of the soft marine sandstone: and, having aggraded its bed with the clay alluvium, lateral erosion commenced, by which means it cut through the dividing-ridge, and allowed itself to be captured by one of the aforementioned neighbouring streams.

These small watercourses have their sources in the outlying Poroporo Range, in the adjacent Tararua foothills, and in the intervening valley. They flowed round the northern end of the Poroporo Range, entering the sea directly opposite. One of them, the Kuku Stream, afterwards raised its bed by depositing alluvium, and flowed over a low col—situated near the northern end of the outlying range—subsequently cutting the small ravine which it still occupies.

Though there is no direct evidence that the "Kimberley Road" stream vacated its original valley before the Ohau had gained access to it, for two reasons such is believed to have been the case. One is that the clay alluvium has not been channelled in the manner it probably would have been had the stream flowed into the Ohau; and the other, and more important, is that had the deviation not taken place the original

valley of the stream would have formed an insurmountable barrier to the Ohau River when the course of the latter was changed in the manner to be described later.

The structure and lithological character of the material of the inclined plain of marine deposit (raised beaches) may now be examined. I am indebted to Mr. John Young for a hint as to the origin of this formation. From original observations made while travelling up and down the railway he concluded that it was nothing more or less than an extensive series of raised beaches, and I have since proved—to my own satisfaction at least—that such is indeed the case. At the foot of the ranges the raised-beach formation is composed of sandstone, but further out from them—in Levin Borough, for example—the formation consists of an upper bed of sandstone, a middle zone of yellow clay, and a basal layer of sandstone, the first and last being identical in all respects. Along the lower slopes of the Tararua foothills especially, the thickness of the raised-beach formation varies according to its remoteness from or proximity to the summits of the Ohau, Otaki, and other fans. Two miles south of Shannon the sandstone lies on the lower northern slope of the Ohau fan, and there has a thickness exceeding 500 ft. Opposite Levin its thickness was originally 200 ft. to 240 ft., but has since been much denuded.

The raised-beach formation is evidently a double one. When the country sank (terminating the early Pleistocene elevation), and the sea advanced over the land in this locality, sandy beaches were formed, only to be submerged and superseded by others as the subsidence continued. When the subsequent uplift took place, the sea while receding repeated the process of deposition, and formed a second series of sandy beaches above the first. The intercalated masses of clay represent, of course, the finer sediment laid down while the sea was advancing and receding, and also when this portion of the country was at its recent minimum elevation—*i.e.*, when the sea washed the Tararua foothills.

The sandstone of the formation is usually rudely stratified, and generally finely laminated, the laminae sometimes exhibiting false bedding. Its colour varies from light and dark grey to various shades of red and yellow. Quartz grains, which constitute the greater part of the sandstone, are coated with iron-oxide in the red and yellow varieties, and associated with black particles in the grey. Ripple-marks are of frequent occurrence in the sandstone, usually at some little distance from the upppermost sea-margin at the foot of the hills, and are without doubt due to the friction of fairly deep water, and not to the action of wind.

In this district both the clay and the sandstone are quite destitute of fossil remains. This deficiency is probably due to the seas which then washed these shores being too turbid to be favourable to the life of shell-fish and similar creatures which were likely to be preserved in the fossil state; or it may be that shells which were originally preserved have since been removed by dissolution. In some places, especially at the foot of the Arapaepae Range, the sandstone outcrops are seen to be riddled, or even honeycombed, with tubular holes, usually from ½ in. to 1 in. in diameter. The absence of fossil remains within these holes renders it difficult to determine whether they were the homes of marine worms or borers, or have merely been made by land-insects since the uplift. The size of the perforations and certain other characteristics seem, however, to disfavour the latter suggestion.


PHYSICAL CONFIGURATION
OF
HOROWHENUA
IN THE
LATER PLEISTOCENE
PERIOD SECOND STAGE
Kopu anga Stream
Ka wha Ridge
North west course of the Ohau River
OHAU RIVER
Kimberley Road
(flood plain)
Stream
Stream
Kuku
Sandhills
piling up
OHAU RIVER
TASMAN SEA

The southern extremity of the newly uplifted coastal plain just described lies about two miles south of Paekakariki. The cliffs which border the sea further south begin at this point to run inland. These cliffs attain in some places a height of 800 ft., and do not rise perpendicularly from the sea margin, but form precipitous scarps fringed at the foot with jagged rocks which lie slightly above high-water mark. As these cliffs strike inland (as a result of the uplift) and recede more and more from the present shore, they are by the formation of talus slopes and other effects of subaerial denudation gradually transformed into steep hills which present comparatively unbroken faces. The best examples of the former sea-cliffs are to be seen near Otaki and Ohau. Although the flat land (marine sediment) first appears near Paekakariki, there are abundant signs of uplift, and also of prior depression of the country, as far south as Porirua Harbour.

The coastal plain of marine deposit varies in the different localities between Paekakariki and Wanganui in both width and elevation. The uplift was probably greatest midway between the two extremities, and the altitude of the upper edge of the sandstone increases at the southern end, apparently with some irregularity, as that point is approached. This irregularity may really be only apparent and not actual, for in some cases it is certain that subaerial denudation has proceeded so uniformly that though the original surface of the sandstone has been considerably lowered the original superficial slope remains unaltered, and the denuded surface is liable to be mistaken for the original one.

The projection of the coast (Kenakena) near Waikanae is, with the exception of the numerous river-mouths, the only irregularity in the grand sweep of the present beach lying between Paekakariki and Wanganui. This projection, which lies exactly opposite the Island of Kapiti, has doubtless been formed by the flow of the tides round the ends of that island. The meeting of the tidal currents on its lee has caused the suspended sediment to be precipitated, thus forming a sandy ridge partly sub- and (by the rise of the land) partly supra-marine. Should the uplift of the land continue, Kapiti, by the extension of this ridge, will eventually become a peninsula.

In the immediate neighbourhood of the Ohau River the principal stream which dissected the coastal plain of marine sediment was the Koputaroa. Taking its rise in the southern end of the Arapaepae Range, and receiving many affluents from the western slopes of the same, it flows northwards into the Manawatu River. During its, geologically speaking, short life the Koputaroa has passed through many vicissitudes, and though the stream is rather insignificant a review of its life-history will perchance serve to indicate the nature of similar sediments and operations of larger watercourses, the conditions under which such sediments were deposited, and the manner in which their actions and operations were effected. When seen in miniature, origins, modes of action, and cause and effect are more easily studied and understood than when the same phenomena occur on a larger scale.

Towards the termination of the Pleistocene period—that is, when the Ohau River flowed in the shallow "north-west" channel, and this portion of the country was at a somewhat lesser elevation than at the present day—the valley which is now occupied by the Koputaroa Stream was transversely divided by a low sandstone ridge. This ridge lay directly between

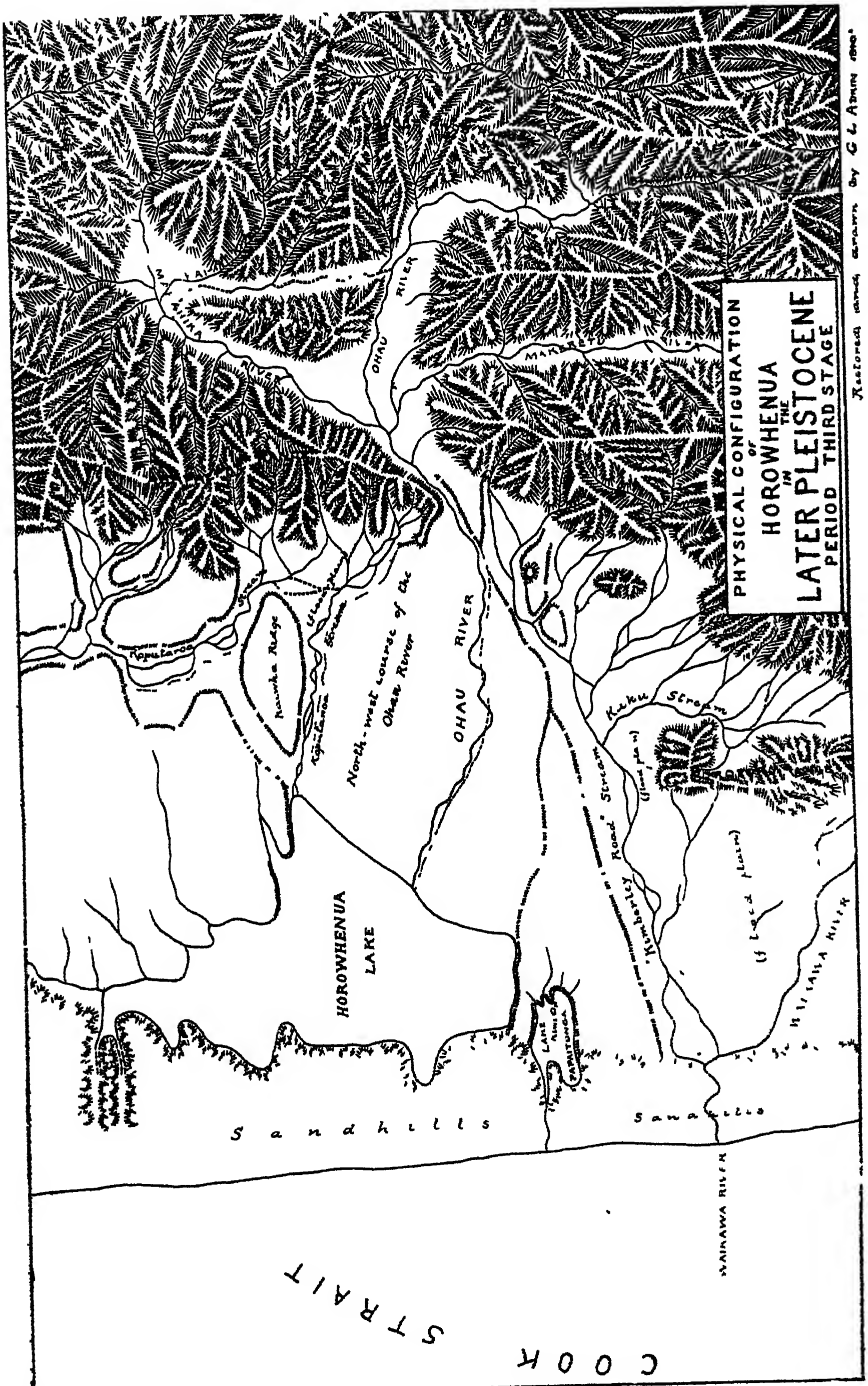
its two remaining extremities, which may still be seen – one near the northern end of the Koputaroa Road, and the other a little north of the north-east corner of Levin Borough.

North of this ridge the drainage was then the same as now, but on the southern side a considerable change has occurred. The Upper Koputaroa Stream—*i.e.*, the portion south of the dividing-ridge, took its rise in the southern extremity of the Arapaepae Range, flowed parallel to it as far as the present position of Queen Street, and then, bending north-west and west, flowed into the Ohau River near the point where it then entered the sea. The Upper Koputaroa was divided from the Ohau River by another low sandstone ridge extending from near the source to the junction of the former with the latter. The "Kaiwha" ridge (such being the name by which it was known to the old-time Maoris) varied from a quarter to half a mile in width, and its summit was about 25 ft. above the beds of the Upper Koputaroa and Ohau Rivers, though later it was in some parts considerably lowered—apparently by pluvial erosion.

While deepening and widening its valley the Upper Koputaroa removed part of the ridge which divided it from the lower part of its present valley, and, deserting its connection with the Ohau, formed a continuous stream which poured its waters into the Manawatu River. A base-level of vertical erosion having been established, lateral erosion became important, so that the Koputaroa attacked and removed the upper portion of the "Kaiwha" ridge, thereby gaining access to the old "north-west" channel of the Ohau River, which was by that time vacated, and therefore dry. The surface-slope of the Ohau fan preventing an overflow of the Koputaroa to the south-west or west, deflected it toward the north-west and caused it to hug the southern side of the "Kaiwha" ridge, and by lateral erosion to cut back its bounding scarp. The sandstone of the ridge was, however not so entirely removed as to expose the underlying fan.

After attaining the base-level of erosion as mentioned above, the Koputaroa began to fill its valley with alluvium derived from the Arapaepae Range. This deposition of material was probably the result of a similar process on the part of the Manawatu River—the one keeping pace with the aggradation of the other. Being in a state of stable equilibrium, the Koputaroa (when the pivot of its motion was in the breach of the "Kaiwha" ridge) by repeated oscillations from one side of its course to the other flowed and deposited material, sometimes on the south side, and sometimes in its valley proper, on the northern side of the "Kaiwha" ridge. This process was continued until the alluvium had reached its present thickness and structure.

During its recent outflowings along the line of Queen Street to the centre of Levin a second bifurcation of the Koputaroa Stream occurred, this time near the Horowhenua Butter-factory. At this point the stream by building up its bed was able to cross a low portion of the "Kaiwha" ridge, and after an interval, and again by aggradation, this time of its newly-acquired channel, it entered the shallow valley of a small stream which formerly flowed westward into Lake Horowhenua. Taking possession of this small valley, the Koputaroa deposited material in it for the remainder of the time of its outflow in this direction, thrusting forward its alluvium as far as the intersection of Queen Street and Tirotiro Road. Both the first and second branches of the westward outflow of the Koputaroa Stream reached and entered the then more extensive Horowhenua Lake.


PHYSICAL CONFIGURATION
OF
HOROWHENUA
IN THE
LATER PLEISTOCENE
PERIOD THIRD STAGE
OHAU RIVER
North-west course of the Ohau River
OHAU RIVER
Kuku Stream
HOROWHENUA LAKE
Sandhills
Sandhills
WAIKAWA RIVER
COOK STRAIT

Since the excavation of the shallow channel it now occupies the Koputaroa has, of course, been confined to its principal valley, and again pours the whole of its waters into the Manawatu River.

The alluvium of the Koputaroa and its tributaries, being fairly typical of the deposits of the other streams which convey the drainage of the Tararua foothills across the coastal plain, is worthy of some notice. In surface form there is a marked contrast between the deposits of the Koputaroa and those of its tributaries. This difference is due to the dissimilarity in the gradients of their beds, the bed of the trunk stream having at that time, as now, a much gentler slope than had those of its tributaries. The Koputaroa spread its alluvium from one side of its valley to the other in gently sloping sheets, while its tributaries formed laterally coalescing fanlike deposits, each deposit having its apex in the gully of the stream to which it owes its origin. The deposits of the tributary streams are not true fans, because they were modified by the presence of the lateral spurs of the Arapaepae Range, which separated their upper portions.

Besides having a gentler surface-slope, the alluvium of the Koputaroa differs from that of any one of its tributaries in other respects; the area it occupies is greater, though its thickness is less; and its contained rock *débris* consists of well-rounded pebbles and boulders, and not, as do the tributary deposits, of angular fragments. The alluvium of the Koputaroa itself consists of masses of gravel, grit, and boulders, surmounted by patches of yellow clay. The total thickness probably does not anywhere exceed 30 ft., and, though the thickness of the lower portion is fairly constant, the upper clayey division varies—in some places swelling out to a depth of 5 ft. or more, and in others thinning away to the upper surface of the underlying gravel. These masses of superficial clay frequently contain numbers of sporadic stones of various size. Of these the largest observed was a greywacke boulder, roughly rhomboidal in form, but nevertheless well water-worn. It lay just below the surface of the clay, and was found to weigh 320 lb., its greater diameter being 28 in., its lesser 20 in.

From recent observations made in Victoria by Mr. Guppy it has been found that muddy water, having a greater specific gravity than that which is free from suspended particles, is able, even when flowing at a moderate velocity, to transport boulders of considerable size. From this it will be seen that the presence of large sporadic stones in a deposit of fine silt, and their transportation, by a stream of no great magnitude, to positions some miles from the parent rock, are phenomena not difficult to be accounted for. These facts seem to indicate that when the Kuputaroa Stream first began to deposit material it was a muddy torrent washing down large numbers of various-sized stones; but after it had raised its bed by deposition its flood-waters spread, in the absence of any well-defined channel, over the whole of the floor of its valley, and, while depositing clay, also rolled down and disturbed the comparatively few pebbles and boulders which happened to come within the range of its action.

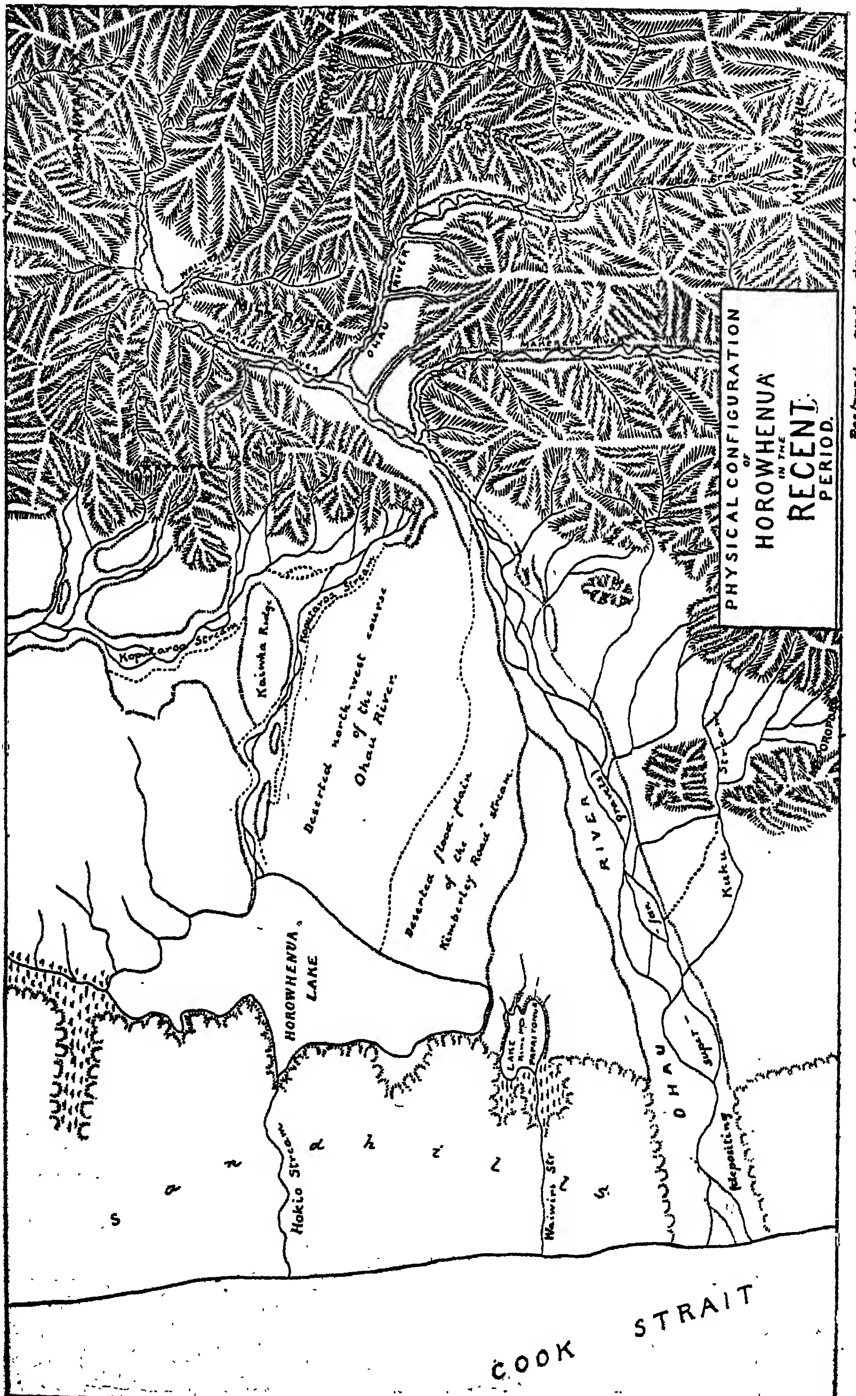
The Ohau River flowed in, and gradually widened, its "north-west" valley, until the sea had receded, in this vicinity, to about five miles from the ranges, when a bar, or perhaps sandbanks, were formed at the mouth of the river. By the action of wind and waves, combined with the uplift of the land, the bar or sandbanks were raised above sea-level, and sand-dunes were piled up, at first obstructing and afterwards completely blocking the river at the point where it entered the sea.

In this manner the Horowhenua Lake was formed. The waters of the river gradually banked up behind the sandy barrier, finally filling the wide channel as far up as the present site of Levin. At the time of its maximum extension the Horowhenua Lake must have had an area of between five and six square miles, its former eastern and south-eastern margins being indicated by the presence of a black soil on the surface of the shingle of the Ohau fan. The uppermost edge of the area of black soil extends from Levin to Weraroa, and from thence along the Beach Road to the State farm, and is, of course, a relic of the swamps which fringed the former successive margins of the lake. During its maximum extension the greatest depth of the lake was about 100 ft., the level of its waters being for a while kept fairly constant by an overflow between the sandhills to the sea. When, however, by the enlargement of this outlet the Hokio Stream came into existence, the surface of the lake was more or less gradually lowered until it reached its present level, thereby reducing its area by three-fourths, and diminishing its depth by more than 70 ft. The irregular swamps at the north and south ends of the lake are the relics of arms of that sheet of water when it had attained its greatest extent, or are abortive attempts to gain an outlet to the sea, or perhaps both.

Former levels of the Horowhenua Lake are indicated by the position and elevation of the extremities of the alluvial deposits of streams which at one time flowed into it. The previously mentioned "Kimberley Road" stream flowed into the southern end of the lake when its level was rising. The Koputaroa has also left memorials of the former higher levels of the lake. The first branch of its western outflow reached the lake when the surface of the latter had attained its maximum altitude—about 110 ft. above the present sea-level; while the second branch entered the lake when its surface had been lowered to about 70 ft. above that datum-line.

At the present time the Horowhenua Lake has an area of 900 acres, its surface is 36 ft. above sea-level, and its greatest depth probably does not exceed 30 ft. The lake derives its water-supply from the overflow of the adjacent swamps and from their interfluent streams, and its only outlet is the Hokio Stream, the sluggish waterway which meanders between the sandhills to the sea. The six islands situated near the western and southern shores were artificially constructed by the Maoris in the early part of the last century to serve as fortresses in their intertribal wars. Some are now, however, more or less submerged through the wasting-away of the perishable vegetable matter of which they were partly constructed.

The sandhills which enclose the Horowhenua Lake on its western and southern shores have kept pace with the uplift of the land, so that they now cover the strip of country, three miles wide, which borders the sea. On the southern boundary of the county the belt of sandhills is also three miles in width, but at its northern end the blown sand has spread inland for over six miles. The most advanced inroad of blown sand is situated near the northern end of Lake Horowhenua, where a comparatively thin stratum extends from the main belt of dunes to the Heatherlea cross-roads. This tongue of land has long ceased to drift, but it can be distinguished from the underlying raised-beach sandstone by its finer texture, its less regular structure, the absence of parallel laminae, and its hummocky upper surface. The superimposition of the blown sand upon the raised-beach sandstone can also be seen about one mile south of Lake Horowhenua.


PHYSICAL CONFIGURATION
OF
HOROWHENUA
IN THE
RECENT
PERIOD.
Restored and drawn by C L ADAM
OHAU RIVER
Deserted north-west course of the Ohau River
Deserted flood-plain of the Kimberley Road stream
HOROWHENUA LAKE
Hokio Stream
Waiwiri Str
Kuku
COOK STRAIT

The general arrangement of the sandhills is in ridges at right angles to the coast-line. Their culminating point between Paekakariki and the Manawatu River is Moutere, 288 ft., and situated between the northern end of Lake Horowhenua and the sea. The surrounding sandhills have a general altitude of 170 ft., and vary in character considerably. Great wastes of bare drifting sand border the coast-line, but further inland the dunes are covered with manuka scrub and grass, so that in these parts the accumulation has now ceased.

The hollows between the older ridges and hills of drifted sand are occupied by grassy flats, swamps, or lagoons. The last named are very numerous, though their area seldom exceeds a few acres. Papaitonga, the largest of the lagoons, is situated in the wedge-shaped sandstone area lying between the former and the present course of the Ohau River. It occupies a hollow (the former valley of a small stream) on the junction-line of the raised-beach sandstone and the hills of blown sand. Extensive swamps border the western shore of Papaitonga, and a stream connects it with the sea. The smaller island, Motu Ngarara, is artificial, but Kiwi Island is an isolated mound of raised-beach sandstone.

The Ohau River flowed into the Horowhenua Lake until the latter had attained its maximum area. At this juncture the deflecting force which had caused it to continually erode its left bank compelled the river to vacate its "north-west" channel, and to flow across the plain of raised-beach sandstone in its present position, but on a much higher level. A moment's consideration will show that the deflection was southwards, which in a river flowing west is from its right bank towards the left. This fact gives some indication as to the nature of the force which impelled the Ohau River to continually attack its left bank during the occupation of its "north-west" channel. Ferrel has shown that moving bodies on the earth's surface, in the absence of other controlling forces, are deflected to the left in the Southern Hemisphere. This law has already been applied to the Canterbury rivers,* and there is no doubt that the deflective force produced by the earth's rotation was the agency which caused the Ohau River to alter the direction of its flow. Having reached its present position, the deflection of the river ceased, owing to the retardation and suppression of the deflective force, partly by superficial obstacles—*i.e.*, the unfavourable configuration of the land-surface, viz., the Poroporo Range—and partly by the awakening of other forces which introduced a new cycle of action into the history of the Ohau River—viz., the excavation of the valley it now occupies.

Upon attaining its present position the first act of the Ohau River was to make for itself a valley in the raised-beach sandstone, and to deepen it until the surface of the underlying fan was again denuded, and also slightly incised. This erosion was due to the sandstone having a gentler surface-slope than had that part of the "valley plain" which lay above its limits, and to the tendency of the river to equalize the gradients of the different portions of its bed. Soon after this erosion of the sandstone the Ohau River began to channel its former deposits.

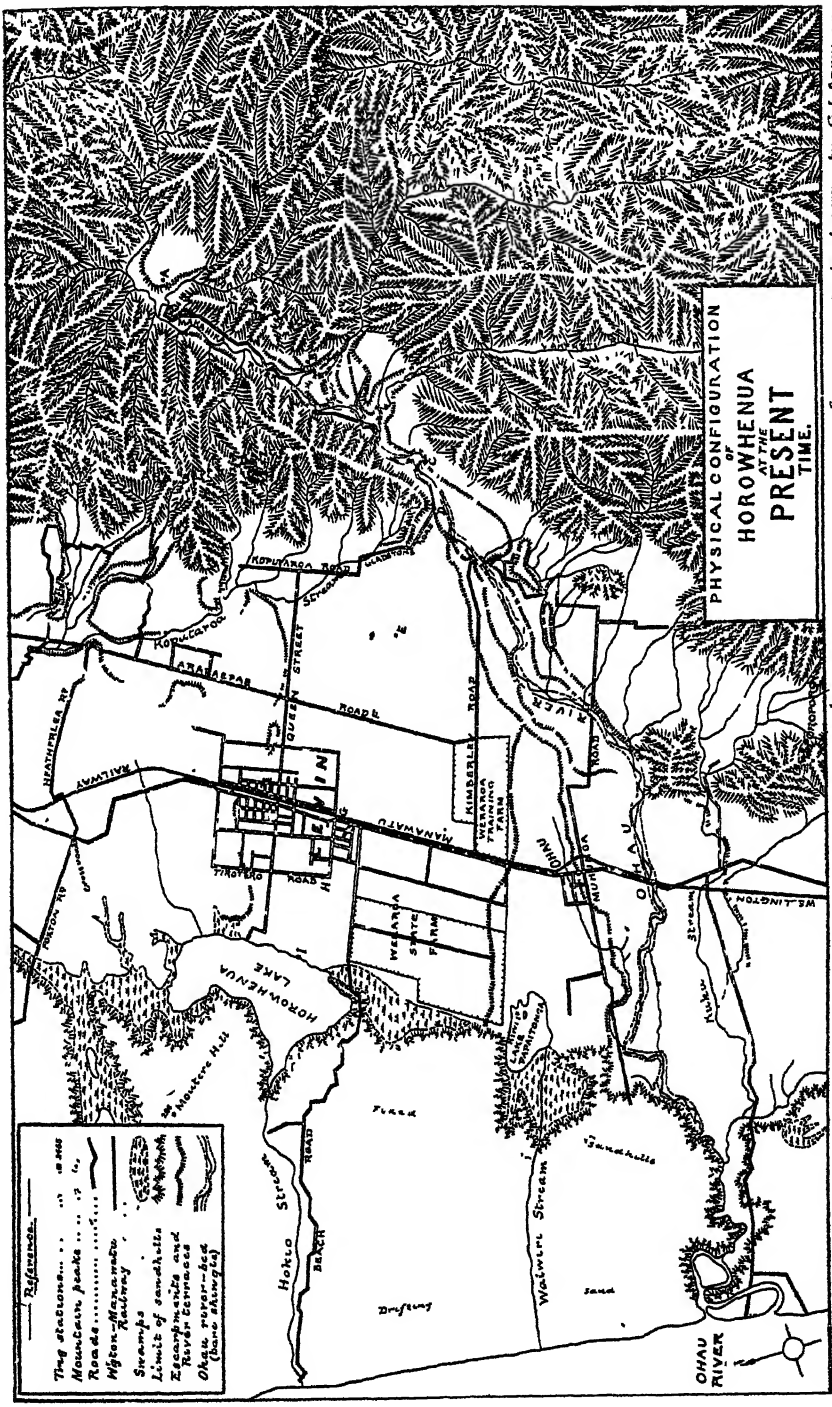
The gradual diminution in the slope of the surfaces of the fan and "valley plain" had an important effect upon the subsequent action of

* F. W. Hilgendorf: "The Influence of the Earth's Rotation on the Course of the Rivers on the Canterbury Plains," Trans. N.Z. Inst., vol. 39, p. 206.

the Ohau River. As has been shown in the appended table, this slope is very similar to a *thalweq*, or erosion-curve, being relatively steep in its upper parts, but gradually becoming flatter (with some irregularity) as it is descended. At that time the chief endeavour of the river was apparently to *reduce* the steepness of its bed; and on this account, and as a result of the general progressive diminution of the superficial dip of its former deposits, the upper and middle parts of the "valley plain" were the first to be incised. The material from this excavation was washed down, and spread over the surfaces of the lower part of the "valley plain" and the upper part of the fan: and it was also deposited to the depth of some 20 ft. on the floor of the valley in the raised-beach sandstone. Lateral erosion on the part of the river then came into play, and in the last-mentioned locality the sides of the valley were cut back—down to the level of the material just previously deposited. This lateral erosion was effected in such a manner as to cause the resultant flood-plain to have a convex surface when viewed longitudinally. In forming this part of the flood-plain the river cut sideways, on its right bank, not only through the sandstone side of the valley, but it also notched (laterally) the slope of the underlying fan. Vertical erosion again attaining an ascendency, another flood-plain was formed somewhat below the level of the first, and this time extending from the upper edge of the "valley plain" to some distance down the slope of the fan. Subsequently, periods of lateral erosion and the formation of successive flood-plains alternated with periods of vertical erosion, and in cases when the flood-plains were not totally destroyed by the further action of the river their fragments were left to form the terraces which are now so common in the several portions of the Ohau Valley.

Owing to its straightness and uniform width, the Lower Makahika Valley, at the commencement of the erosion of the early Pleistocene deposits, was extremely liable to be swept from side to side by floods, so that, with the exception of two or three fragments which now indicate the altitude of the original surface, the Makahika branch of the "valley plain" was destroyed and washed away. As the excavation progressed—lateral erosion being in part superseded by vertical—the lower flood-plains were less affected by the action of the river than the original surface was, and are therefore more extensively preserved. The truncation of the spurs in the Makahika Valley appears to have been effected in the Tertiary epoch, since thick masses of early Pleistocene deposits can be seen abutting upon their truncated ends.

An examination of the escarpments of the terraces which have been cut in the "valley plain" shows that there are of the latter two distinct types. In one the terrace-face consists either of shingle, gravel, &c., from summit to base, or has a considerable thickness of these materials resting on the country rock, while in the other type the country rock is surmounted by only a comparatively thin layer of water-worn detritus. The first type of terrace shows that the Ohau has incised its Pleistocene deposits (which fill the primary, or pre-Quaternary, valley of the river) either in the middle or at one side of the valley, while those of the second type indicate that the river has cut laterally and then vertically into the bounding hills, and, in forming the subsequent flood-plains, deposited a veneer of gravel and shingle upon the successive platforms which it carved in the ancient base rocks.



Scale: two miles to an inch.

The gravels, &c., of the Ohau fan and valley deposit, and also of the recent terraces, consist of greywacke, soft slates, fragments of conglomerate, and red and green quartzose material in corresponding proportion to their occurrence in the country rock of the district.

Since the excavation of its present valley the Ohau River, along the lower part of its course, has raised its bed by the deposition of fine sediment in much the same manner as the Waimakariri River has done in the neighbourhood of Kaiapoi. These alluvial flats, which constitute the fertile lands about the Lower Kuku Stream, have their origin where the terraces of the Ohau merge upon the surface of its fan, and extend from thence to the coast, though there, as elsewhere, their limits are hidden by blown sand. The establishment of these aggraded alluvial flats has prevented the inroads of the dunes on a narrow strip bordering the left bank of the Ohau River. This is the only place within the area shown on the accompanying maps where the fertile land, which elsewhere lies contiguous to the foot of the ranges, approaches to within one mile of the sea-beach.

The question now presents itself, What caused the Ohau River to excavate its present valley? A cursory examination of the locality would doubtless lead the observer to the conclusion that the present terraced valley of the Ohau River is the direct result of the (geologically) recent plication of the folds, and consequent slow upheaval, of the Tararua Ranges, and also of the adjacent sea-bed. Such, however, was not the case. It is true that upheaval has taken place, as shown by the occurrence of raised beaches, and it is highly probable that such was due to crustal movements in the Tararua and Ruahine Ranges; but there is evidence to show that the uplift and the formation of the present Ohau Valley were not coincident, and therefore the former was not the direct cause of the latter. The river did not *commence* the excavation of its valley until the land had well-nigh reached its *present* elevation.* The Ohau flowed in its north-west channel until the land was within 30 ft. of its present elevation, and after that again it flowed in the same direction as it does now long enough to excavate the sandstone to a depth of about 100 ft.—all before it *commenced* to incise the upper portion of its "valley plain."

These facts point to a very considerable lapse of time between the beginning of the uplift and the commencement of the erosion of the Ohau Valley, so that a more satisfactory explanation of the latter operation must now be sought for.

The theory recently put forward by an eminent Canterbury geologist† appears to conform with the facts of the case under notice. He considers that one of the causes which will enable a river to excavate its channel is "the failure of the supply of waste"—that is, the failure of the supply of detritus with which the river is aggrading its bed or which it is transporting to lower levels. Concisely, the theory is as follows: Other factors remaining constant, a cessation or diminution of the supply of transportable

* By "the excavation of its valley" is meant the erosion by the Ohau River of its former deposits—*i.e.*, the "valley plain" and fan accumulations. Being due to causes other than those now being considered, the origin of the second valley in the raised-beach sandstone does not come into the present discussion.

† R. Speight: "Some Aspects of the Terrace-development in the Valleys of the Canterbury Rivers," Trans. N.Z. Inst., vol. 40, p. 16.

rock *débris* within a catchment-area will cause the contained river to deepen its channel. In this district the ascertainable facts appear to support and confirm this view.

Though at the present time the basin of the Ohau River contains only a few insignificant areas rising above the timber-line, in the early Pleistocene, when the river was building up its fan, a very considerable proportion of the mountains among its sources and upper reaches was bare of arboreal vegetation. The former lower altitude of the timber-line in relation to the sources and upper reaches of the Ohau River was, of course, due to the greater elevation of this part of the country at that time.

A covering of dense forest acts as a shield and filter—controlling the impetuosity of the water following heavy rain; binding the soil together and protecting the underlying rocks: allowing only the finest silt to be transported to lower levels; and, perhaps most important of all, preventing the formation of landslips. A striking, though by no means rare, example of the last-mentioned attribute of a forest covering was observable from Levin on Friday, the 3rd September, 1909. Dry weather followed by rain — a very favourable series of circumstances — produced their usual effects on the mountains; but, though innumerable slips were visible on those ridges of the Tararuas lying above the limits of the bush, not more than half a dozen were to be seen upon the nearer forest-clad ranges.*

It follows, then, that in the early Pleistocene, when the land hereabouts stood at least 1,000 ft. higher than now, the areas bare of forest suffered severely from the action of the elements—rain-storms swept away the soil; the alternate action of sun and frost shattered the rocks thus exposed; and landslips and freshets carried the resultant rock *débris* to the valley-bottoms, furnishing the Ohau and its tributaries with an abundant supply of "waste" wherewith to build up its deposits in the lowlands.

This state of affairs was brought to a gradual close by the following subsidence of the land. It would appear that the upward extension and growth of the forest did not keep pace with the subsidence, because, had it done so, the excavation of the present Ohau Valley would have commenced in the middle Pleistocene—the period of recent minimum elevation of this part of the country. It seems, therefore, that the forest was slow in adapting itself to, and taking advantage of, the new conditions, and by failing to check the supply of "waste" delayed the excavation of the valley to the Recent geological period—almost to the present day.

In the foregoing an attempt has been made to account for the varied physical features of the district, the various geological formations, and the peculiarities of surface-configuration. As previously stated, the absence of fossils will no doubt force investigators to fall back on stratigraphical evidence and the evidence of the slow crustal movements—first epeirogenic, then orogenic—when attempting to place the formations of the district in their correct position in the geological scale. The problems of the district are by no means exhausted, but, as those still unsolved apparently do not affect the continuity of the chain of events, their non-solution is in the present instance of no great importance.

* That the nearer ranges are not immune from landslips is shown by the fact that when the bush is felled they are particularly liable to be disfigured by these hideous scars.

TABLE OF FORMATIONS DESCRIBED IN THE ABOVE PAPER.

Formations.	Composition of Formations.	Origin.	Age.	Alternative Name.
Rocks of Tararua Ranges	Greywacke, slates, &c.	Marine (?)	Early Mesozoic (?)	
Pre-existing plain (lateral slope of Cook Strait valley)	(?)	(?)	Pliocene (?) ..	.
Ohau Valley deposit and fan	Boulders, shingle, sand, and clay-seams	Fluviatile	Early Pleistocene	Period of uplift, great elevation, and subsidence.
..	..	..	Middle Pleistocene	Period of minimum elevation.
Raised beaches ..	Soft sandstone and clay	Marine.	Later Pleistocene to Recent	Period of latest uplift.
Alluvium on the latest coastal plain. [Flood-plains, &c., of the minor streams]	Gravel, boulders, clay	Fluviatile (minor)	Recent .	
Terrace gravels, &c., in the Ohau Valley	Shingle and clay	Fluviatile	Recent ..	
Blown sand ..	Sand	Aeolian	Recent to present day	

ART. XLV.—*Some Notes on the Marlborough Coastal Moraines and Waiau Glacial Valley.*

By Professor JAMES PARK, F.G.S., Otago University.

[*Read before the Otago Institute 4th October, 1910.*]

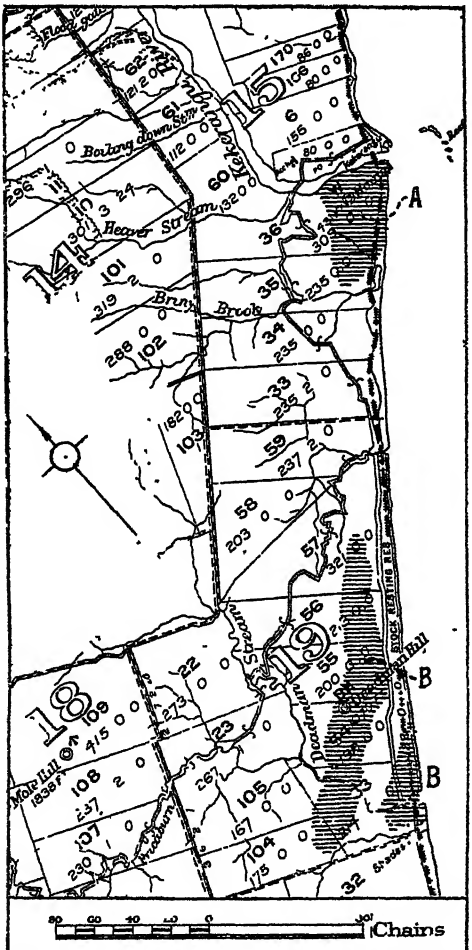
Plates XX–XXII.

THE Marlborough coastal moraines extend from the shores of Cook Strait near Cape Campbell southward to Shades Creek, a distance of twenty-six miles. I have elsewhere* spoken of the three greatest of these glacial deposits as the Cape Campbell Moraine, the Kekerangu Moraine, and the Shades Creek Moraine, but a recent examination of the maritime belt in which they occur has led me to the belief that these moraines, although now more or less detached, at one time constituted a continuous deposit, having

* James Park: "The Geology of New Zealand," 1910, p. 201.

been formed by an ice-sheet that descended from the Kaikoura Mountains to what is now the shore-line of the north-east portion of the South Island.

There is indisputable evidence that the confluent glaciers which formed this ice-sheet extended eastward beyond the present strand, but just how far cannot be determined until more data are available.



MAP SHOWING KEKERANGU AND SHADES MORAINES, MARLBOROUGH.

A. Kekerangu Moraine. B. Shades Moraine.

At the mouth of Kekerangu River the moraine-material rises into bold headlands over 400 ft. high, and, moreover, forms rocky ledges and reefs that can be traced seawards for some half a mile, until they disappear in the deep water.

Three miles north of Kekerangu River, at Shaw's Falls, there is a considerable development of morainic material; and at many points between that place and Lake Grassmere, and between Lake Grassmere and the Wairau Valley at Blenheim, much glacial *débris* of a similar character is to be seen.

In the Kekerangu Valley, about two miles from the sea, a strip of glacial moraine composed of material identical with that found in the coastal moraines is entangled in a powerful fault that follows the foot of the range. This faulted moraine is beautifully exposed in the steep banks of Heaver's Creek (see Plate XX).

At the mouth of Shades Creek there are two bands of morainic material—namely, a narrow band entangled in a fault-plane close to the point where the main coastal road crosses the stream, and a broader band parallel with the first and about 30 chains to the westward. This second greater band varies from 10 to 40 chains wide, and extends from the south side of Shades Creek northward two miles or more towards Kekerangu, crowning and forming the coastal ridge which culminates at Deadman's Hill, 1,070 ft. high.

The Shades Moraine is splendidly exposed to view in the sea face of Deadman's Hill, along the foot of which the Blenheim coach-road passes southwards to Kaikoura. Enormous blocks of grey Amuri limestone are

seen projecting from the steep slopes fronting the sea; and half a mile from the sea the course of Shades Creek is blocked up and rendered impassable with piles of fossiliferous boulders that have fallen from the adjacent morainic ridges (see Plate XXI).

The presence of such a vast accumulation of ice-formed and ice-borne detritus on the present shore-line offers a temptation to speculate as to the former existence of an ice-sheet that may have stretched far beyond the present strand. Of a great extension beyond the present shore-line there is, however, not much evidence. An examination of the detritus shows that it is mainly fluvio-glacial and glacial, such as might very easily be formed at or near the edge of a piedmont ice-sheet.

The morainic reefs off the mouth of the Kekerangu River lie at their furthest limit half a mile from the shore. They may possibly extend as submerged reefs another half-mile or more to seaward; but, notwithstanding this possibility, I am inclined to think that the present strand marks approximately the eastern extension of the Pleistocene glaciers during the period of maximum refrigeration.

The Kekerangu and Shades Moraines, although so far north, rank among the finest examples of glacial deposits in the South Island, and among the most accessible. They are, unlike the Cape Campbell Moraine, close to the main coach-road connecting Flaxbourne and Kaikoura, and can be reached from either Blenheim or Kaikoura in a day.

A prominent feature of these moraines is the presence in them of large angular blocks of different rocks plucked from the bed-rock in the neighbourhood or transported from a distant watershed.

In the face of the cliff forming Homai, the south headland at Kekerangu (Plate XXII), there are many large angular blocks, among which two conspicuous masses of Amuri limestone* immediately catch the eye when standing on the beach. The most northerly mass measures 32 ft. by 30 ft. by 20 ft.; but it should be mentioned that these dimensions may be much greater, as the distance the block extends into the cliff cannot be seen. The southerly block measures 38 ft. by 20 ft. by 11 ft., the last dimension being the distance the mass is seen to project beyond the cliff-face.

Some 25 yards south of the last mentioned block of Amuri limestone, and at about the same height, there is a large mass of soft blue foraminiferous clay from the Awatere beds near Flaxbourne or Seddon, which measures in the two dimensions that are exposed 30 ft. by 22 ft.

Besides these, this moraine also contains large slablike masses of soft Tertiary sandstone, with numerous fossil shells, and blue shaly clay with leaf-impressions, the largest slab seen by me measuring 10 ft. long, 6 ft. wide, and 2 ft. thick.

The included blocks of rock in the Shades Moraine are more numerous and larger than at Kekerangu. In the face of Deadman's Hill, as seen from the beach, three masses of Amuri limestone are particularly conspicuous. The largest measures in the two dimensions that are exposed 72 ft. by 24 ft.; the second, 51 ft. by 28 ft.; and the smallest and most southerly, 46 ft. by 32 ft. by 30 ft., the last dimension not being fully exposed.

Mount Vernon Drifts.

These form the Vernon Hills, lying from two to five miles south of Blenheim, and extending from the sea along the west side of the Wairau Valley

* These are shown in fig. 93, p. 202, "The Geology of New Zealand," by James Park, 1910. Photo by A. McKay, F.G.S.

for over twenty miles. They consist of a great pile of fluviatile drifts over 1,200 ft. thick. Towards their base the drifts are intercalated with beds of clay and soft sandstone alternating with beds of gravel. At their base, and resting on the basement rock, which is mainly greywacke and jointed argillite of probably Lower Secondary age, there is a rock-rubble deposit mainly composed of angular blocks of greywacke, few of which exceed 2 ft. in diameter. The material is loosely piled together, and in many respects resembles the terminal moraine of the Hooker Glacier or the lateral moraines of the Tasman. It varies from 10 ft. to 160 ft. thick, and is specially well exposed on the Awatere side of Maxwell's Pass.

The Vernon drifts, with their basal glacial *débris*, form the divide between the Lower Wairau and Lower Awatere, rising in places to a height of over 2,000 ft. above the sea. In places they rest on the older Pliocene clays of the Awatere series. Like the Shades and Kekerangu deposits, they are in places tilted at high angles, in others traversed by faults. That they are Pleistocene seems almost certain.

Waiau Glacial Valley.

The southern portion of Marlborough is traversed by the Inland and Seaward Kaikoura chains, which are separated by the gorgelike Clarence Valley. Ten miles north of the Kaikoura Peninsula the seaward chain pursues a south-west course, which carries it further and further inland, so that when it crosses into the prolongation of the Province of Nelson that protrudes itself between North Canterbury and South Marlborough it is no longer a seaward but an inland range of mountains, still forming, as it does further north, the southern wall of the Clarence Valley.

Five miles south of the Kaikoura Peninsula there begins another coastal range that extends southward to Cheviot and North Canterbury. Between this coastal range and the Seaward Kaikouras, now an inland chain, there lies a wide, well-defined valley extending from the Upper Waiau and Hanmer Plains to Kaikoura. When standing at the Hanmer River it is at once seen that this valley was the course followed by the ancient Waiau Glacier as it flowed towards the sea, and also of the Waiau River before the cutting of the present gorge.

The evidences of prolonged and intense glaciation are everywhere present from the Hanmer Plains to the sea at Kaikoura Peninsula, in the shape of smooth, flowing, ice-shorn contours, truncated spurs, spurless ridges, isolated ice-grooved and whalebacked hills remaining in the floor of the glacial valley, *roches moutounées*, and moraine *débris*.

The Waiau glacial valley is easily identified, as the inland coach-road from Kaikoura to the Upper Waiau follows along its floor for the greater part of the way. It is not now drained by a trunk river, but is crossed transversely by a number of large streams that descend from the southern slopes of the Seaward Kaikouras, and reach the sea by deep, narrow gorges cut through the coastal range. Beginning at the Kaikoura end, we first have the Kahautara River and its branches, then the Conway River, and lastly the Mason River, with its tributary the Lottery. These rivers have deeply dissected the ancient glacial floor, which, however, can be clearly traced at Greenhills, Highfield, and Mason.

Near the north end of the chain of *roches moutonnées* running along the floor of the glacial valley on the south side of the Conway, and locally know as the "Whaleback," there are piles of morainic *débris* mainly composed of angular blocks of Amuri limestone and Saurian greensand mingled with

greywacke drift. The angular blocks appear to have been plucked from the south end of the Whaleback, where they occur *in situ*, and carried to their present place, a distance of six or eight miles. Exposures of this glacial *débris*, but not the best, are seen on the coach-road soon after crossing the Conway going southward.

In the overdeepened portions of the glacial valley there occur considerable deposits of stratified sands and clays, in places containing seams of impure lignite. These deposits were probably formed in the period of fluviatile activity that everywhere throughout the South Island appears to have followed the retreat of the Pleistocene glaciers.

The Kaikoura Peninsula lies at the seaward end of the Waiau glacial valley, the course of which is about north-east to south-west.

Art. XLVI.—*The Geology of the Kermadec Islands.*

By W. Reginald B. Oliver.

[*Read before the Philosophical Institute of Canterbury, 19th October, 1910.*]

Plates XXIII–XXVI.

The first account of the geology of the Kermadec Islands is contained in a paper by Mr. S. Percy Smith, F.R.G.S., written after a short visit to the group in 1887, in the Government steamer "Stella." for the purpose of annexing the islands to the Colony of New Zealand (Smith, 1888). Specimens of rocks collected by Mr. Smith were described by Professor A. P. W. Thomas, M.A., F.L.S. (1888, p. 311). Some general information regarding the group is given in Mr. Smith's report on the Kermadec Islands (Smith, 1887). The only other notes on the geology of the Kermadecs that I am aware of are the descriptions by Mr. R. Speight, M.Sc., F.G.S., of a few rocks collected by Professor Park on Macauley and Sunday Islands (Speight, 1896).

As a member of the scientific expedition which was camped for ten months on Sunday Island in 1908, among other things I made a collection of rocks, and noted as well as I was able the geological structure of the island. On the return journey to Auckland, Macauley Island, Curtis Island, and French Rock were visited in turn, when an opportunity was afforded of obtaining a few specimens from these islets. The collection of rocks has been described by Mr. Speight, who in the same paper discusses the geological evidence for the existence of a subtropical Pacific continent (Speight, 1910). I propose now to describe the physical features and structure of the various islands of the Kermadec Group, and, in the case of Sunday Island, the order in which the different series of tuffs and lavas were laid down and the island thus built up by volcanic action on a submerged base. The names used here for the rocks are taken from Mr.

Faulted Moraine, Heaver's Creek, Kekerangu, Marlborough.

Fossiliferous Boulders (Awatere Series) in Glacial Moraine, Shades Creek, Marlborough.

Glacial Moraine, Kekerangu South Head, Marlborough.

Speight's paper and the corresponding numbers of the specimens are quoted in every case. For much help freely given I beg now to tender my sincere thanks to Mr Speight.

SUNDAY ISLAND—PHYSICAL FEATURES

Sunday Island is roughly triangular in shape. Its greatest length is 10.5 km, and its area 29.25 sq. km. The present crater, oblong in shape, the longer diameter being about 3.3 km, occupies a large portion of the island, and contains three lakes (fig. 1 and Plate XXIII). From the crater rim there branch off three main ridges—one runs north-west from Expedition Hill to Hutchison Bluff, another south-west from Mount Junction to Smith Bluff, the third south-east from Moumoukai to the east coast. These with their ramifications form practically the whole of Sunday Island.

With the exception of some level ground in Denham Bay, in the crater and on Low Flat and the adjoining Terraces, the whole of the surface of

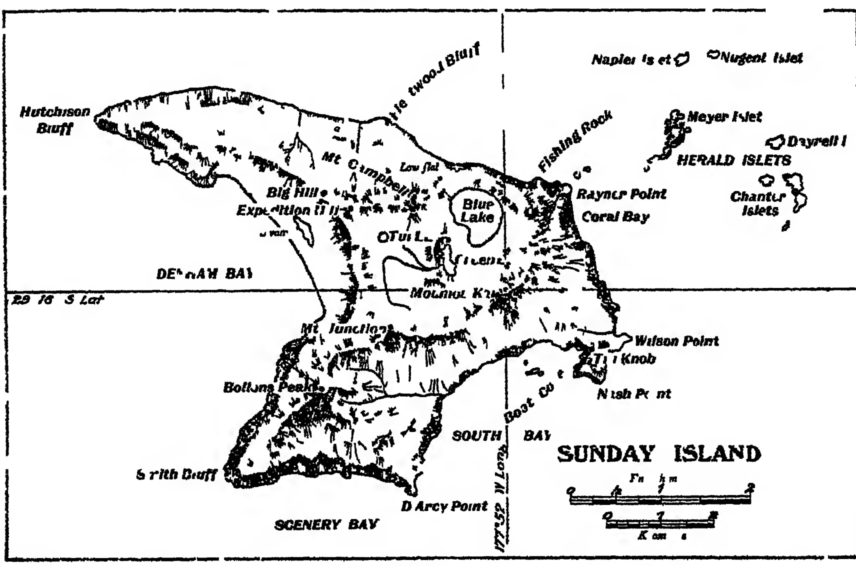


FIG 1

Sunday Island consists of a series of narrow ridges and deep ravines. High cliffs are frequent both along the coast and inland. This extremely rough island, which, though small, is difficult to travel over, has by the action of sea and rain been modelled out of a volcanic cone composed mainly of pumice and other andesitic tuffs.

Green Lake appears to have been the centre from which the last outbursts of volcanic activity proceeded. The water is of a dark bottle-green colour, and has a strong alkaline taste.

At the foot of Expedition Hill is a small sheet of fresh water known as Tui Lake, hidden in the forest. It is difficult to give reasons for the presence of this lake, as, on account of the porous nature of the soil, nowhere else on Sunday Island does water lie in small hollows.

Blue Lake, which is nearly circular in outline and very shallow, lies between the small or inner crater-ridge surrounding Green Lake and the

north side of the large or, as I will refer to it later, Sunday crater ridge. The bottom is a blue volcanic mud, and the water is clear, fresh, and good drinking.

South Bay Gorge bears witness to the vast amount of material removed by subaerial denudation in Sunday Island. The ravines which intersect the hills in all directions are deep, with steep, often precipitous, sides; while the tops of the ridges are narrow, usually 2 m. or 3 m. wide, and sometimes, where not protected by vegetation, razorback edges. The boundary-ridges of South Bay Gorge are pushed back by the action of rains constantly removing the tuffs; hence towards Denham Bay and Scenery Bay they present convex outlines. The largest valleys on Sunday Island—namely, those which descend to sea-level in South Bay and on the north coast, where one has pushed its way right back to the Denham Bay ridge—intersect the older tuffs of the Expedition volcano. Their basins are wide at first, but narrow to gorges at the coast. Hence the depth and shape of the valleys indicate their relative age.

The greater part of the coast-line is formed of sea-cliffs. At their bases are boulder beaches formed of fragments of lava set free by the disintegration of volcanic tuffs. There is a beach composed of coarse gravel in Denham Bay, while at the base of the Terraces and on Low Flat are some sandy beaches.

Herald Islets.

A group of seven rocky islets lying to the north-east of Sunday Island, and known collectively as the Herald Islets, may be divided according to their geological character into three sections—(1) Meyer Island, (2) Napier and Nugent Islets, (3) Dayrell and the Chanter Islets.

Meyer Island.

Meyer Island is composed of beds of a compact yellow andesitic tuff (No. 5*), dipping to the north-west at an angle of about 40°. Lava dykes traverse these beds in various directions, but the general trend is from between north and north-west to between south and south-east. A large dyke composed of dark-grey augite-andesite (No. 8) runs in a due north-and-south direction in the northern islet. The soil on Meyer Island is the loose weathered surface of yellowish andesitic tuffs (No. 10), which, from being continually overturned by burrowing shearwaters (*Puffinus assimilis* and *P. chlororhynchus*), is constantly moving downhill. In a small gully on the western slope is a bed of hard yellowish-grey fine-grained tuff (No. 18), containing impressions of leaves, apparently belonging to the species *Rhopalostylis Baueri* and *Corynocarpus laevigata*. A few plants of *Corynocarpus* are still to be found on Meyer Island, and both species occur on Sunday Island.

Napier Islet.

Napier Islet is composed almost entirely of beds of lava, enclosing here and there blocks of coral, dipping to west-north-west at a high angle. Fragments of coral, calcite incrustations, and water-worn stones were collected on the summit ridge about 60 m. above sea-level. I am indebted

* These numbers refer to the specimens described by Mr. Speight, who uses the numbers originally given to them by me at the time of collecting (Speight, 1910).

to Mr. Speight for the following description of a specimen of lava collected on Napier Islet :—

"No. 11.—Augite-hypersthene-andesite. Forms a large part of Napier Islet, and encloses blocks of coral.

"Macroscopic : A dark-grey rock with small phenocrysts of feldspar clearly visible throughout. Specific gravity, 2·83.

"Microscopic : The groundmass consists of basic labradorite microlites, grains of augite, and iron-oxides, with a little brownish glass present. Phenocrysts of basic labradorite are very common, and contain numerous glass inclusions. The dominant F.M. mineral is hypersthene in large crystals with characteristic cleavages and pleochroism ; augite grains are common, frequently twinned, and with oblique extinction. There is a little olivine present in the form of small grains stained with iron-oxides."

Dayrell Islet.

Dayrell Islet consists mainly of beds of submarine origin, dipping to the north at a low angle, about 5°. The lower beds are composed of hard sandy tuffs containing fossils, the upper ones of a white calcite rock. These are covered by andesitic tuffs (No. 20), whilst lava dykes pierce the islet in various directions. The Chanter Islets are similar in structure to Dayrell Islet. (Plate XXIV, fig. 1.)

On one occasion only I was able to land for about half an hour on Dayrell Islet, when I collected a number of fragments of molluscs and corals. The corals have not yet been examined. Of five species collected, I recognize only one among those found living in the group. The molluscs include the following : *Turbo argyrostomus* L., *Pupura*,* *Clanculus*, *Risella*, *Trochus*, *Amalthea*, *Spondylus ostroides* Smith,* *Pecten kermadecensis* Watson,* *Chama*, *Chione*, *Arca decussata* Sow.* Those species marked with an asterisk (*) also occurred among the recent shells collected on Sunday Island. I am indebted to Mr. C. Hedley, F.L.S., of Sydney, for the identification (though he expresses some doubt) of *Turbo argyrostomus* L. Recent examples of this species have never been obtained on Sunday Island, though M . R. S. Bell knows the fauna well.

STRUCTURE OF SUNDAY ISLAND.

Long lines of high cliffs afford splendid opportunities for observing the structure of Sunday Island. Here will be described the arrangement of the various volcanic beds as seen in typical sections in different portions of the island. Further on in this paper an attempt will be made to describe the order in which the material was ejected from the different centres of eruption.

At the south end of Denham Bay a horizontal stream about 10 m. thick of greyish andesitic basalt (No. 38) is exposed for a considerable distance. Unfortunately, one end is buried under fallen cliff *débris*, but evidently it must terminate abruptly at the base of Expedition Hill (fig. 2). Above the basalt are beds of tuffs extending to the top of the crater-ridge and Mount Junction. These are arranged in two distinct series. The lower beds, about 60 m. thick, are arranged in perfectly horizontal thin even beds, which, I should say, have undoubtedly been deposited under water. They are composed of small fragments of andesitic rocks in a finer matrix, and include many larger rock-fragments. They contain no pumice, and will be

referred to in this paper as the "newer submarine beds." The upper beds are irregular, and doubtless of subaerial origin. They are composed almost entirely of andesitic pumice, including fragments of lava rocks. At the summit of Mount Junction (472 m.) a small angular fragment of hornblende-granite was collected, and high up on one of its southern spurs, over 200 m. above sea-level, a larger boulder was noticed.

In the cliffs beyond the beach the basalt-flow is seen to thin out and finally disappear. Entire cross-sections of other flows are also exposed. They are horizontal, of nearly uniform thickness for most of their length, and taper at both ends. A specimen from one of these beds proved to be a dark-coloured augite-olivine-andesite (No. 26). At the base of the cliffs is a boulder beach composed mainly of fragments released from the volcanic tuffs above as they weather away. At one spot was observed a large water-worn boulder of hornblende-granite about 50 cm. long.

The sections of Big and Expedition Hills as exposed to view in Denham Bay show a series of lava-flows dipping at an angle of about 5° to the north-west. A specimen from one of these is a grey basalt (No. 37); another from a flow lying above is a dark compact andesite (No. 21 Above the lava-flows are volcanic tuffs.

A large landslip which occurred in Denham Bay some six years ago exposed a section of the cliff up to a height of 300 m. The lower part of

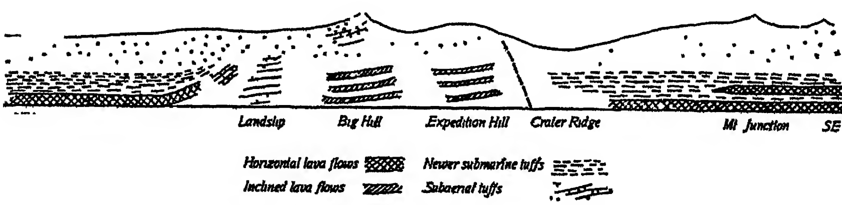


FIG. 2.—CLIFFS IN DENHAM BAY, SUNDAY ISLAND.

the cliff, however, is covered by the fallen material. The section exposed shows no lava-flows, but a series of irregularly stratified beds of andesitic tuffs, not pumiceous, but containing angular fragments of lava rocks. These beds have a northerly dip. Further on a few beds dip at a high angle—about 40°—as though they had been undermined and slipped down; they are adjacent to the next-described submarine series.

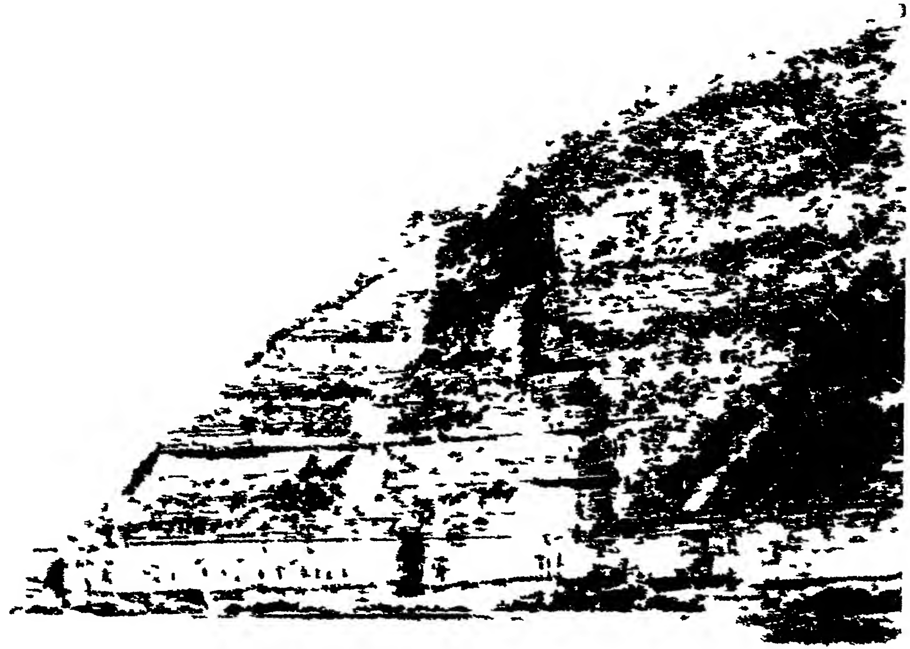
At the north end of Denham Bay the series of beds corresponds in part to those at the south end. At the base is a horizontal flow of andesitic basalt (No. 39), then about 60 m. of evenly stratified submarine tuffs covered by subaerial tuffs, which, however, are not pumiceous. Below the lava at one place a little tuff containing some decomposed wood is exposed.

The extreme point of Hutchison Bluff is quite a bare cliff 300 m. high. It consists entirely of irregular beds of andesitic tuffs. These tuffs consist of a coarse-grained gritty rock, which weathers quickly, containing small fragments of lava. On the north coast, from the Terraces (which cover the bases of the higher cliffs) to near the bluff there are two distinct series of beds, the upper ones superimposed on the eroded surface of the crumpled lower beds. The upper beds are composed entirely of andesitic tuffs (with no pumice), and, dipping generally but slightly to the westward, pass beyond the lower beds near Hutchison Bluff. The lower beds consist of

General View of Crater, Sunday Island, looking North.
Green Lake in foreground. Blue Lake beyond. Napier and Nugent Islets in distance.

Fig. 1.—Chanter Islets.
Showing submarine fossiliferous beds overlaid by white calcite rock.

Fig. 2.—Macauley Island.
Showing sections of basalt stream, pumice tuffs, and covering of scoria. Lava Cascade is below lower provision depot.



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Northern Face of Rayner Point, Sunday Island, showing Newer Submarine Tuffs.

GENERAL VIEW OF CRATER, CURTIS ISLAND AND MACDONALD COVE, FROM TOP OF CRATER RIM.

thin even strata of tuffs which I take to be of submarine origin (referred to as the "older submarine series"). The stratification is perfectly even, though the beds are now tilted in short sections alternately to east and west, as though great lateral pressure had been brought to bear. In two places they are pierced by small intrusions of augite-andesite.

At Hutchison Bluff a core of lava, about 8 m. wide, of burnt and scoriaceous appearance has burst through the submarine tuffs (fig. 3). On the western side a stream of augite-andesite 1 m. to 4·5 m. thick (No. 29) descends from near the top of the core at an angle of about 10°.

Further to the east is another intrusion of augite-andesite (No. 30). Surrounding the lava the tuffs are burnt to a brick-red colour.

The Terraces are a comparatively recent addition to the north side of Sunday Island, and at the base of Big and Expedition Hills abut against cliffs which are a direct continuation of the sea-cliffs extending to Hutchison Bluff. They are composed entirely of pumice tuffs arranged in slightly irregular but generally horizontal beds, apparently of subaerial origin. A specimen of pumice, Mr. Speight informs me, is andesitic in character. Fragments of lava rocks, sometimes 2 m. or 3 m. in diameter, are strewn thickly throughout the pumice tuffs. At the base along the shore-line there is for the most part a boulder

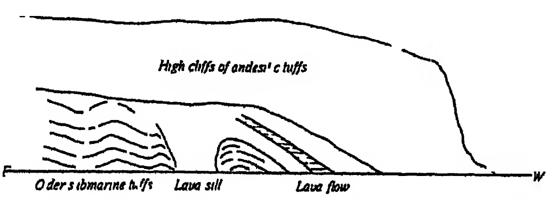

FIG. 3.—INTRUSION OF AUGITE ANDESITE AT HUTCHISON BLUFF, SUNDAY ISLAND.

beach composed of fragments too heavy to be washed away by the sea, which is gradually eating away the comparatively loose tuffs. Among the boulders I gathered samples of hornblende-granite* and andesitic pitchstone (No. 2), and noted that the largest pieces of lava were identical in appearance with the andesites from a large flow of lava in the Sunday crater. Logs of charred wood, recognized as that of *Metrosideros villosa*, the most abundant tree on Sunday Island, were noticed in the tuffs at the base of the cliff. The section exposed at Fleetwood Bluff shows No. 1 Terrace to have been formed during two distinct periods of eruption, in the interval between which two wide valleys some 20 m. deep were formed in the first deposited beds. On the hillside above No. 1 Terrace, about 80 m. above sea-level, is a large boulder of hornblende-granite.

On the east coast of Sunday Island, at sea-level, is a stratum composed of rounded evidently water-worn boulders of all sizes up to 2 m. in diameter, cemented together by a sandy matrix. Above this and conformable to it are the newer submarine tuffs, intersected in Coral Bay by a large dyke running east and west, and overlaid by a flow of basalt (No. 36), above which are pumice tuffs.

In South Bay, near D'Arcy Point, at sea-level, is also a bed similar to that on the east coast, containing water-worn boulders. Several dykes with a general north-west trend intersect the newer submarine tuffs of South Bay. On the shore several small rounded stones of hornblende-granite were seen.

* For a description of the hornblende-granite see Speight, 1910, p. 251

The cliffs in Scenery Bay present a series of lava-flows horizontal in section, and cut by several dykes. Between the lower flows at D'Arcy Point are portions of beds of yellow andesitic tuff (No. 13) of submarine origin. A lava-flow at sea-level in Scenery Bay is composed of dark-grey andesitic basalt (No. 41). A specimen of andesitic basalt (No. 40) from the same locality was taken from a dyke 2 m. to 3 m. wide, and running north-west and south-east.

Titi Knob, which is the name given to a small hill above Boat Cove, is composed of a mass of lava and tuff which shows little orderly arrangement, and is in places thoroughly mixed with coral. A typical specimen of the lava is composed of andesite containing many fragments of coral (No. 22). In one spot on Titi Knob is a rock showing planes of stratification and containing fossils (No. 25). It consists of a coarse gravel composed of grains 1 mm. to 3 mm. long cemented by white calcite. Included are fragments of lava up to 2 cm. long, coral, and molluscan shells. I could not trace this for more than 2 m. or 3 m. in any direction. The fossils collected included fragments of the following molluscan shells: *Trochus*, *Nassa*, *Arca decussata* Sow. (?), *Chione*.

The north side of the Sunday crater ridge consists of pumice tuffs containing numerous fragments of lava rocks and hornblende-granite. Here in several places angular fragments of the granite may be seen projecting from the cliff-face, and those which were extracted were easily crumbled to their coarse constituent grains, whilst on the shore occur numerous water-worn boulders of various sizes up to about 50 cm. long. The pumice tuffs rest on hard andesitic tuffs, apparently belonging to the newer submarine series.

Within the crater on the western side of Blue Lake is a large flow of olivine-andesite (No. 34), dipping gently in a northerly direction, and which may be traced until its upper surface reaches the level of the lake and disappears under the pumice tuffs of the north side of the crater-ridge. Above this lava-stream to the summit of Mount Campbell, 285 m. above sea-level, there is nothing but pumice tuffs.

At the base of Moumoukai, on the eastern side of Blue Lake, a good section is exposed. The lower beds, about 40 m. in thickness, are evenly statified horizontal yellow andesitic tuffs (No. 14) of submarine origin and similar to those at D'Arcy Point, but differing in their composition to the larger series of newer submarine beds which enter so largely into the formation of the lower portion of Sunday Island. Above the submarine beds of Moumoukai is a stream of andesite (No. 9) identical in external appearance with the olivine-andesite on the opposite side of Blue Lake, and apparently only another part of the same flow. Above this are several other lava-flows, while the upper half of Moumoukai, in common with the whole upper part of the large Sunday crater rim, is composed entirely of pumice tuffs.

The inner crater surrounding Green Lake also consists of pumice tuffs. On the southern shore of the lake was found a fine-grained tuff (No. 32) containing rounded bombs.

From the foregoing description it will be gathered that Sunday Island is a tuff cone, with here and there near sea-level a few lava-flows and dykes. In three places only — Moumoukai, within the crater; Big Hill, in Denham Bay; and Scenery Bay—are there exposed to view cross-sections of a number of lava-streams. The floor of the crater is near sea-level, and cliffs exposing sections are the rule both within and without the crater, yet nowhere was hornblende-granite found *in situ*.

HISTORY OF SUNDAY ISLAND.

The Herald Islets may be looked upon as fragments of the wall of an ancient crater of which the greater portion has been demolished by the sea, and, though entirely detached from Sunday Island, I have no hesitation in considering this crater the first to appear in the vicinity of Sunday Island. There is no evidence to show that any land actually existed above sea-level in this locality when the disturbance which resulted in the Herald crater took place. The presence of littoral marine mollusca and corals, of which many fragments are entombed in the beds of Dayrell and Chanter Islets, however, indicates shallow-water conditions, and, even if a fragment of a once more extensive continental area did remain above the surface of the ocean, whatever living forms existed on it were entirely destroyed by subsequent volcanic eruptions, as no characteristic continental forms of life are without doubt indigenous to the Kermadec Islands.

The probable date of this eruption cannot, in a geological sense, be very remote. Those fossil molluscs which have been identified with tolerable certainty all belong to living species, most of them still existing in Sunday Island waters. One, *Turbo argyrostomus*, is not known to occur alive in the Kermadec Group, but is found in Queensland and the Pacific islands. Bearing in mind the fact that about 11 per cent. of the vascular plants of Sunday Island are endemic, the newer Pliocene would perhaps be sufficiently far back for the age of the Kermadec Islands.

Contemporaneous with the formation of the Herald volcano a small eruption occurred in Boat Cove, Sunday Island. This also was chiefly submarine, as what now remains of the crater-walls consists of andesite lava with many fragments of coral entangled (Nos. 22, 25).

Meantime some yellow andesite tuffs (Nos. 13, 14) and a little lava were being deposited under water further to the westward. These are now exposed at D'Arcy Point and on Moumoukai within the crater; the crumpled older submarine beds at Hutchison Bluff also were perhaps deposited about this time. The land, however, was rising, and a series of eruptions followed, resulting in the formation of a third volcano, whose crater was on the eastern side of Expedition Hill (the probable position of the inner wall of this crater, which may be called the Expedition crater, I have indicated by the broken oblique line in fig. 2). To this volcano I assign practically all the lava on Sunday Island—namely, most of the flows and dykes seen in section in the cliffs in Denham Bay, Scenery Bay, and within the crater (rocks Nos. 21, 37, 40, 41, 9, 34). Over all was laid a thick covering of andesite tuffs, from which evidently was derived the material for the newer submarine series.

After this copious outpour of lava the volcanic forces apparently were suspended for a while, a boulder beach was formed along the shore-line (which at one spot on the east coast and another in South Bay, coincides with the present shore-line), and the walls of the Expedition crater were considerably denuded by marine and subaerial agencies. Next followed a period of subsidence, denudation proceeding apace, resulting in the deposition of the newer submarine series. (Plate XXV.) Meantime some lava (Nos. 38, 39, 26) welled up and flowed in horizontal sheets in Denham Bay, and later some dykes penetrated the tuffs in other parts. At the base of the cliffs in Coral Bay I extracted a large *Trochus* shell, belonging to a species still living in Sunday Island, from a rough angular block of lava. This could only have come from a lava-flow some height up the

cliff. The amount of subsidence can be gauged by the thickness of submarine tuffs—namely, about 60 m. These submarine beds were covered with a considerable thickness of andesite tuffs with irregular bedding, probably ejected from the Denham Bay crater. Upheaval afterwards took place, and has continued till the present time, the island meanwhile being considerably reduced by the action of sea and rain.

An eruption resulting in the present large, or Sunday, crater was the last serious attempt of the island to add to its size. A violent outburst forced a way through the lava-flows forming the northern slopes of the Expedition volcano. No molten rock came to the surface in this new crater; only pumice tuffs containing numerous fragments of lava rocks and fewer of hornblende-granite and andesite-pitchstone (No. 2). The lava-streams of the northern slopes of the Expedition volcano were shattered to fragments, some of which, 2 m. or 3 m. in diameter, were hurled up as far as Fleetwood Bluff. The pumice tuffs ejected from this crater form, as far as I can judge, the whole of the lower northern portion of the crater-rim, Mount Campbell and the upper part of the crater-rim resting on the extinct Expedition volcano. The Terraces, which originally must have joined the crater and extended for a considerable distance out to sea, were also the product of the Sunday crater. In describing their structure I have already pointed out that the largest boulders freed by marine denudation at Fleetwood Bluff are identical in external appearance with specimens (Nos. 9, 34) from the great ruptured lava-stream within the crater. It is in the ejectamenta of this crater alone that fragments of hornblende-granite were observed.

The struggles of the dying volcano of Sunday Island had not yet quite ceased, for an eruption on a small scale occurred within the very walls of the large Sunday crater, and resulted in the formation of a small pumice cone, of which Green Lake occupies the centre. The fine-grained tuff (No. 32) containing bombs is the product of the Green Lake crater.

Recent Volcanic Activity on Sunday Island.

Two eruptions have been recorded since the discovery of Sunday Island.* One occurred in 1814, and is recorded in the *Sydney Gazette* of the 17th September of that year (Smith, 1896); the other took place about the year 1872, and of this an account was printed in the *Southern Cross* (Sterndale, 1884; Smith, 1888, p. 337).

There are still many signs of volcanic activity on Sunday Island. Earthquakes are fairly frequent, and are usually followed by small landslips. Four rather severe shakes and many slight tremors were experienced on Sunday Island during the first ten months of the year 1908.

Fumaroles occur in several parts of Sunday Island.

Macauley Island.

Macauley Island, distant 109 km. from Sunday Island, is somewhat circular in outline, and entirely surrounded by cliffs, which can be scaled

* Mr. H. I. Jensen (Proc. Linn. Soc. N.S.W., vol. 31, p. 661) states that a violent eruption occurred in the Kermadec Islands in 1902. This may be a slip of the pen, as the vegetation in the crater has apparently never been disturbed since the new growth after the outbreak of 1872, and the inhabitants did not mention an occurrence, though I believe Sunday Island may have been deserted about the year 1902.

at one place only, the Lava Cascade. Mount Haszard, the highest point above sea-level, 230 m., is near the western side, and from here the land slopes away gradually to the eastward. Several deep ravines have been cut through the pumice tuffs by the action of rain-water.

The base of the island is composed of flows of basalt (No. 42), the upper surface of which, from being fairly high in the western cliffs, falls rapidly at first, and is then nearly horizontal. The basalt collected by Mr. Smith, and described by Professor Thomas (1888, p. 312), came from the Lava Cascade, which, according to Mr. Smith (1888, p. 341), belongs to a period later than that to which belongs the flows represented by rock No. 42. Above the basalt were beds of andesitic pumice (No. 43), averaging about 75 m. in thickness. From these beds Mr. Smith collected pitchstone, obsidian, and pumice, and from the surface of the island a basaltic scoria (Thomas, 1888, pp. 312, 314), which forms beds of considerable thickness overlying the pumice tuffs. (Plate XXIV, fig. 2.)

Haszard Islet is composed of lava, pumice, and scoria corresponding in the relative position to the beds of Macauley Island, but dipping in the opposite direction.

CURTIS ISLAND.

Two islets, the smaller of which is evidently but a detached portion of the outer edge of the crater-rim of the larger, are distant 35 km. from Macauley Island, and separated from one another by a strait about 400 m. wide. The larger islet is a crater-rim, one side of which has been broken away, giving place to a small inlet (Macdonald Cove), in which a landing can be effected in easterly weather. The inner side of the crater-rim is mostly precipitous, and appears to be composed mainly of volcanic tuffs.

Over the crater-floor, about 4 m. above sea-level, are scattered many holes full of boiling water or mud, and much sulphur and siliceous sinter. The sea-water near the landing is kept quite warm by the hot water flowing into it. (Plate XXVI.)

FRENCH ROCK.

This most southern member of the Kermadec Group, distant 83 km. from Curtis Island, is a mere rock about 250 m. in length, rising to a height of about 50 m. above sea-level. It is composed of lava, including olivine-andesite (No. 46), much burnt and scoriaceous in places, and pierced by dykes.

CONCLUSION.

Here I propose to summarize the evidence relating to the origin of the Kermadec Islands, referring firstly to that indicating a continental extension, and secondly to the several lines of evidence supporting the supposition that the islands have never exceeded much their present area.

According to Mr. Speight, the occurrence of many fragments of hornblende-granite in the pumice tuffs on the north coast of Sunday Island indicates the presence in close proximity of a granite foundation which at one time no doubt formed a land-surface (Speight, 1910, pp. 244, 249). Mr. Speight considers the claims of the islands to be classified as continental are worthy of serious consideration, and adduces certain lines of evidence, chiefly biological, to support this view.

The only tuffs from which fragments of hornblende-granite were actually taken were those ejected by the last, or present, large crater of Sunday Island, and the presence of all the boulders noticed on the sea-shore and elsewhere can be explained by the release of fragments consequent on the removal of the exposed face of sea-cliffs and surface of the tuffs by marine and subaerial denundation. My observation, therefore, support the opinions expressed by both Mr. Smith (1888, p. 344) and Professor Thomas (1888, p. 315)—namely, the presence of boulders of plutonic rocks on Sunday Island could be explained by the supposition that they have been brought up from great depths by volcanic agency.

In the foregoing description of the geological structure of Sunday Island, and attempt to deduce therefrom the history of the island, I have endeavoured to make it clear that (except for the inclusion in some of the lavas and tuffs of coral and hornblende-granite respectively, and some calcite no doubt derived from coral in the Herald Islets) Sunday Island and the adjacent Herald Islets are built up entirely of volcanic materials ejected from five principal points of eruption. The first eruptions were submarine, but shallow-water conditions obtained. Elevation then took place, and much lava flowed above sea-level. The land-surface was afterwards considerably denuded, and during a temporary subsidence volcano tuffs were deposited under water. Lava-flows were meantime becoming less frequent, and finally ceased, but the ejection of tuffs above sea-level, the last of which were entirely pumiceous, continued for a long period, so that the main portion of the islands at the present time consists of tuffs which are rapidly disappearing into the ocean. The geological structure of Sunday Island, therefore, shows it to be built up in comparatively recent times on a submerged base, and that it never exceeded its present dimensions more than can be accounted for by marine denudation.*

The biological evidence which, with apparent exceptions, seems to support the supposition of an oceanic origin for the Kermadec Islands will now briefly be reviewed.

From a study of the flora, Mr. Cheeseman was convinced that the Kermadec Islands have received their plants by transoceanic migration (Trans. N.Z. Inst., vol. 20, p. 163). My further investigations, as far as I am able to judge, confirm his views. I see no plants in the flora whose presence in the group cannot reasonably be attributed to the agency of ocean-currents (drifting logs), wind, and birds.

As illustrating classes including land-animals the *Gastropoda* and *Crustacea* may be mentioned. About eighteen terrestrial species of the former and fewer of the latter were collected. They agree in being all small, and in this respect what ought to be expected of members of these classes capable of crossing wide stretches of ocean, where floating trees have probably been the means of transport.

If the presence of migratory birds in numbers at certain seasons of the year is an indication of the spot being on an old shore-line, then the Kermadec Islands afford little evidence of this character for such a connection.

* The island Eua, in the Tonga Group, has, according to Mr. J. J. Lister, had a history closely parallel to that of Sunday Island as sketched in this paper. Gabbro occurs as boulders on the shore, while garnet and tourmaline are found in the volcanic tuffs (Lister, Quart. Jour. Geol. Soc., vol. 47, p. 590). Mr. H. I. Jensen's views with regard to Eua, however, are similar to Mr. Speight's concerning Sunday Island quoted above (Jensen, Proc. Linn. Soc. N.S.W., vol. 31, p. 641).

Occasionally stragglers find their way there, but no migratory birds can be considered regular visitors to the group.

The presence in the Kermadec Islands of the Pacific rat (*Mus exulans*), the candlenut-tree (*Aleurites moluccana*), and the Polynesian ti (*Cordyline terminalis*) is perhaps suggestive of a continental connection; but I have given reasons elsewhere for supposing these to be introduced by Natives, of whose occupation on Sunday Island there is ample evidence (Oliver, 1910, p. 137; also see p. 539 of this volume).

List of Works referring to the Geology of the Kermadec Islands.

1884. Sterndale: "Sunday Island." Appendix to Journals of the House of Representatives of New Zealand, A.-4, p. 64.

1887. Smith, S. Percy: "The Kermadec Islands; their Capabilities and Extent." Wellington.

1888. Smith, S. Percy: "Geological Notes on the Kermadec Group." Trans. N.Z. Inst., vol. 20, p. 333.

1888. Thomas, A. P. W.: "Notes on the Rocks of the Kermadec Islands." Trans. N.Z. Inst., vol. 20, p. 311.

1896. Speight, R.: "Notes on some Rocks from the Kermadec Islands." Trans. N.Z. Inst., vol. 28, p. 625.

1896. Smith, S. Percy: "Volcanic Activity on Sunday Island in 1814." Trans. N.Z. Inst., vol. 28, p. 47.

1910. Oliver, W. R. B.: "The Vegetation of the Kermadec Islands." Trans. N.Z. Inst., vol. 42, p. 123.

1910. Speight, R.: "Petrological Notes on Rocks from the Kermadec Islands; with some Geological Evidence for the Existence of a Subtropical Pacific Continent." Trans. N.Z. Inst., vol. 42, p. 241.

Art. XLVII.—*Notes on Reptiles and Mammals in the Kermadec Islands.*

By W. Reginald B. Oliver.

[*Read before the Philosophical Institute of Canterbury, 1st June, 1910.*]

There are neither land-reptiles nor land-mammals indigenous to the Kermadec Islands, the group presenting in this respect one of the main features of oceanic islands. When the islands were discovered rats were plentiful, but reasons will be given below for considering them as introduced through the agency of man. Two marine animals—the green turtle and the humpback whale—regularly visit the group, while others are occasional visitors.

Mr. R. S. Bell, of Sunday Island, informed me that besides the green turtle one or two individuals of another species, probably the hawksbill, have been noticed from the shore. Mr. T. F. Cheeseman, F.L.S., F.Z.S., mentions a water-snake, which, from the description given him by Mr. T. Bell, he supposes to be *Pelamys bicolor* (Cheeseman, 1888).

On several occasions during September, 1908, I observed dolphins in Denham Bay, Sunday Island. Mr. Bell says that the sperm whale has been seen from the north coast of Sunday Island. On one occasion a portion, about 2 ft. long, of a large cuttlefish was cast up on Low Flat Beach. This fragment was possibly the remains of an animal which a whale had made a meal from, as it is known that sperm whales kill and eat these gigantic cephalopods.

The following notes are mainly from material gathered during a ten months' stay on Sunday Island, in 1908, as a member of the scientific expedition which originated with Mr. W. L. Wallace, of Timaru.

Chelone mydas. (Green Turtle.)

A large female specimen of the green turtle was shot by Mr. R. S. Bell off the rocks at the south end of Denham Bay on the 23rd May, 1908.

Turtles were noticed chiefly during the summer months — January to March—often as many as five or six being seen at one time. An observer standing on the shore at a little height can watch them browsing on a species of alga (*Pterocladia capillacea*), which grows abundantly on rocks in water down to about 5 m. in depth. Apparently, whilst in Sunday Island waters turtles eat no other kind of food. Every few minutes they come to the surface for a few seconds to breathe, but on the slightest alarm these timid reptiles swim swiftly away. They do not breed in the Kermadecs, but go north to warmer regions.

Megaptera boops. (Humpback Whale.)

A few humpback whales were noticed in Denham Bay in the latter part of August, 1908. During September their numbers increased, while in October and November they were common all round Sunday Island; at Macauley Island also, on 12th November, a large number were seen. They had their calves with them, and probably were migrating southwards. During their northward migration they are not seen from Sunday Island.

Mus exulans. (Pacific Rat.)

Specimens of the Pacific rat examined on Sunday Island agree in every particular with those from Funafuti, as described by Mr. E. R. Waite, F.L.S. (1897, p. 174), except that the under-surface, including inside of limbs, is light buff, or sometimes pale grey; fur pale grey at base; upper surface of feet light buff, hairs short; hairless parts of feet pink.

Skulls of Sunday Island examples appear to be proportionately more slender than the skull of the Funafuti specimen. The zygomatic arch is less prominent, thus giving a smaller breadth, whilst the nasal bones are narrower. These differences are apparent in the table of measurements given below, where the corresponding figures recorded by Mr. Waite for the Funafuti specimen are given for comparison.

Of thirty-four specimens of rats from Sunday Island of which I have measurements, I select the ten largest of each sex as best showing the size of full-grown individuals :—

Head and Body.	Tail.	Length of Head	Ear.	Forearm and Hand.	Hind Foot.
		Males.			
Mm	Mm.	Mm	Mm.	Mm	Mm
130	146	39	17·5	35	28·5
131	145	40	17	35	28
132	155	40	18·5	35	28·5
133	138	40	17·5	34	27·5
133	156	41	17·5	34	29
136	145	39	17·5	35	28·5
138	150	41	19	35	27
141	147	42	18	35	28
144	151	41	17·5	34	28
147	147	43	18·5	35	28·5
		Females.			
125	146	38	18	33	28
127	144	39	17	33	27
127	146	37	17·5	32	27·5
128	144	38	17·5	34	28
129	138	40	17	33	27
129	152	39	18	34	28
130	140	39	18	34	29
130	140	38	17·5	34	28
133	143	40	17·5	34	28
137	146	41	18	34	27·5

Thus the male is, on an average, larger than the female. Apparently in the female the tail is proportionately longer than it is in the male; but this is probably due to the fact that the males are the more pugnacious, and consequently have their tails bitten more frequently. A large number of specimens collected for examination had to be rejected because more or less of the end of the tail was missing.

Measurements of Skulls of Rats from Sunday Island; also Measurements of Skull of Rat from Funafuti for Comparison.

——	Sunday Island.					Funafuti
	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.
Greatest length	33·5	33·5	34·6	34·7	35·5	35·0 ?
,, breadth	15·5	16·4	16·8	16·0 ?	16·5	17·6
Nasals, length	13·2	13·0	13·5	13·0	13·5	14·0
,, greatest breadth ..	3·5	3·5	3·4	3·5	3·6	4·0
Interorbital breadth	5·4	5·5	5·5	5·5	5·5	5·5
Brain-case, breadth	13·5	13·5	13·8	14·0	14·0	13·6
Diastema	9·0	9·6	10·0	10·0	10·0	9·0
Anterior palatinal foramina ..	5·5	6·5	5·7	5·7	6·4	5·7
Condyle to incisor-tip ..	21·5	22·5	22·5	23·0	24·4	23·0 ?
Coronoid-tip to angle ..	9·5	10·0	9·5	9·8	10·0	9·2

Habits.

During the first week in January, 1908, few rats were seen, but their numbers increased gradually, until in March and April they were plentiful.

In June rats were very numerous about our camp in Denham Bay, being seen frequently in the daytime, but more especially in the evenings, when they invaded our whares.* They searched everywhere for food, but did not gnaw into any of our boxes. Although naturally timid, they would explore every part of the whare if we kept quite still, and, as soon as the light was out, jump up on the table near which two of our party slept, and would sometimes even run over us as we lay in our bunks. We poisoned them periodically with arsenic, but it merely checked their numbers for a few days, after which they appeared as numerous as ever.

As showing the large number of rats that exist on Sunday Island, the following figures are given on the authority of Mr. R. S. Bell. He estimated that in three years 44,000 were killed by poisoning and other means, while on one occasion 173 were caught in a single night near the cultivations in Denham Bay by means of a trap made with a harbour-buoy.

The rats decreased in numbers during July. In August, on wet evenings but few were to be seen, but on fine nights a fair number came about our whares. During September and October very few were noticed.

That the rats disappear into the ground during the summer months seems certain, for on one occasion Mr. R. S. Bell accidentally dug out one of their burrows and discovered a number of rats which appeared somewhat sleepy and dazed on being turned out into the daylight. During their out-season they usually retire to their holes in the daytime; when surprised in the forest they immediately make for their burrows and disappear. It is probable that they breed in the ground, as young ones were noticed chiefly at the end of summer.

Their food consists principally of fruits. Bananas, oranges, passions, grapes, and figs all disappear before hordes of rats, and the settlers on Sunday Island must protect their fruit-trees if they wish to have any share of the fruit. A piece of tin nailed round the stem at a distance of about 2 ft. from the ground will prevent rats from climbing the tree, but bananas must be cut just as the first signs of yellow begin to appear in the fruit, and placed in some position where rats are unable to get at them.

Sunday Island rats are not strictly frugivorous, but, on the contrary, will eat any kind of food. Birds and their eggs, when they are to be obtained, are eaten, also the flesh and fat of goats, while specimens of rats I had gathered for examination when thrown out were usually devoured by their own kind. The beaches were constantly searched, and any fish or other animals cast up by the sea eaten by rats.

Origin of the Rat in the Kermadecs.

When first discovered by Europeans, Macauley Island was described as having a "great number of rats and mice" (Watts, 1789, p. 228). There is no similar record for Sunday Island, though this island is now overrun with the Pacific rat (*Mus exulans*), which could scarcely have been introduced by Europeans, who have been the only visitors to the group since its discovery, a little more than a hundred years ago, and who would have introduced,

* Huts made of a framework of poles, with sides and roofs of rushes, palm-leaves, or banana-leaves.

if any, the more widely distributed and powerful grey and black rats. These, however, are unknown in the Kermadecs.

Remarking on Lieutenant Watts's narrative, Mr. Cheeseman says, "This would seem to prove that the species, whatever it may be, is truly indigenous" (Cheeseman, 1888, p. 163). Mr. O. Thomas, in his note on some rats collected on Sunday Island, says that the Pacific rat "has probably travelled from island to island in Native canoes, or on floating logs, &c." (Thomas, 1896, p. 338). Now, if floating logs carried rats to the Kermadecs in the first instance, then the species would be truly indigenous, provided it had not been introduced through the agency of man to the country whence it migrated to the group.

The Kermadec Islands are, from a biological standpoint, oceanic in character. In order to reach the groups, therefore, rats must cross about six hundred miles (1,000 km.) of ocean, which is the distance to the nearest land. The time which would be taken by a floating tree drifting this distance negatives the possiblity of rats reaching the group in this manner.

The Pacific rat occurs in all the principal groups of islands in the Pacific Ocean. As many of the inhabitants of these islands used it as an article of food, it would often be carried intentionally from one island to another. Probably, however, it was more often carried accidentally in the Native canoes. Being a small, timid, and harmless animal, it would not be troubled much by the Native navigators, and this, possibly, may explain its wide distribution.

On Sunday Island there have been found from time to time stone axes of a similar pattern to those made by Maoris. Other evidence of Native occupation of the group is furnished by the large holes on the Terraces, which, from their position, number, and size, have evidently been made by some Native race. Probably they were chiefly *ruas*, or storehouses for food. In some of the larger holes, however, were large water-worn stones, no doubt brought from the beach below. These larger holes may be *hangis* where the Natives prepared their ti-root.

There is no doubt then that the Kermadec Islands were at one time inhabited by Natives, and it is by them, either accidentally or intentionally, that I consider the rat has in all probability been introduced.*

List of Works referring to Sunday Island Rat.

1789. Watts, Lieutenant: Chapter xx of "The Voyage of Governor Phillip to Botany Bay." London.

1887. Smith, S. P.: "The Kermadec Islands; their Capabilities and Extent," p. 24. Wellington.

1888. Cheeseman, T. F.: "On the Flora of the Kermadec Islands; with Notes on the Fauna." Trans. N.Z. Inst., vol. 20, p. 163.

1896. Thomas, O.: Proc. Zool. Soc., 1895, p. 338.

1897. Waite, E. R.: "The Atoll of Funafuti, Ellice Group" (Mammals). Mem. Aust. Mus., 3, p. 165.

* In my paper on the "Vegetation of the Kermadecs" (Trans. N.Z. Inst., vol. 42, p. 173) I have included the candlenut (*Aleurites moluccana*) and the Polynesian ti (*Cordyline terminalis*) in the list of introduced plants, as they are not distributed generally in the forest, but are found only in habitable parts of Sunday Island, where they appear to be survivors of the abandoned cultivations of a Native race.

Art. XLVIII.—*On Some Calyptoblast Hydroids from the Kermadec Islands.*

By F. W. Hilgendorf, M.A., D.Sc.

[*Read before the Philosophical Institute of Canterbury, 1st June, 1910.*]

In 1908 a small party of naturalists sailed to the Kermadec Islands by the New Zealand Government steamer, and stayed on the islands for about ten months—that is, until the next voyage of the steamer to the islands. During their stay Mr. W. R. B. Oliver, of Christchurch, collected some hydroids, and it is through his kindness that I am able to describe those mentioned below.

There is, as far as I can find, no previous record of any hydroids from this group of islands. From their geographical position it would be supposed that the affinities of the fauna of the group would be mainly with New Zealand, since it lies only about eight hundred miles north-east of Auckland, and this supposition is supported by the few hydroids found. The hydroids of New Zealand itself have not been at all completely examined. The species described prior to 1895 are catalogued by Farquhar in the "Transactions of the New Zealand Institute," vol. 28. p. 459, and to that catalogue I shall refer for all papers and synonyms up to that date.

Since Farquhar's list appeared I can find only the three following papers on hydroids from the New Zealand region: viz., Hilgendorf (Trans. N.Z. Inst., vol. 30. p. 200), Hartlaub (Zool. Jahrbuchern, 1901, p. 349), Benham (Subantarctic Islands of N.Z.. p. 306).

Besides the hydroids, the collection as handed to me contained a part of a skeleton of an antipatharian, part of a madreporian coral, several floats of a species of a *Physalia*, one or two *Polyzoa*, and some eggs of molluscs. Most of these, however, were not in a fit state for determination or description. They remain in my hands.

Campanularia caliculata var. makrogona (V. Lendenfeld).

(For references and synonyms, see Farquahar, Trans. N.Z. Inst., vol. 28, p. 459).

Hab.—Dunedin Harbour and Wellington Harbour, in New Zealand; Australia; Kermadec Islands (on seaweed, Denham Bay, Sunday Island).

In reference to *Campanularia*, Hartlaub (*loc. cit.*) correctly points out that in my paper in Trans. N.Z. Inst., vol. 30, I was wrong in transferring *Campanularia* and *Eucopella* to *Hypanthea*, since this last genus differs from the others in its reproduction.

Halecium tenellum (Hincks).

H. tenellum Hincks, Ann. Nat. Hist., 3rd ser., vol. 8, p. 252; Brit. Hyd. Zooph., p. 226. *H. labrosum* Alder, Ann. Nat. Hist., 3rd ser., vol. 3, p. 354.

Hab.—England; Australia; Kermadec Islands (on *Polyzoa*, in Denham Bay, Sunday Island).

Two species of this genus have been found in New Zealand, but neither here nor in Australia does the genus seem common. Bale (Cat. Aus. Hyd. Zoophytes, p. 65) says he has a specimen that he thinks is *H. tenellum*, and V. Lendenfeld (Proc. Linn. Soc. N.S.W., ser. 1, vol. 9, p. 405) found specimens at Port Phillip that he was inclined to refer to this species. My specimens were not quite typical, having a great tendency to produce only two cups.

Sertularia minima (Thompson).

(For synonyms and references, see Farquhar, Trans. N.Z. Inst., vol. 28, p. 462; also Hilgendorf, Trans. N.Z. Inst., vol. 30, p. 209.)

Hab.—Timaru and Dunedin, in New Zealand; Australia; Cape of Good Hope; Kermadec Islands (on seaweeds cast up on Denham Bay beach, Sunday Island).

Synthecium elegans (Allman).

(For synonyms and references, see Farquhar, Trans. N.Z. Inst., vol. 28, p. 465; also Hilgendorf, Trans. N.Z. Inst., vol. 30, p. 211.)

Hab.—Bluff, Stewart Island, and Dunedin Harbour (New Zealand): Kermadec Islands (Denham Bay, Sunday Island).

The specimens were growing on the base of an *Aglaophenia*, to be mentioned below.

The interthecal spaces were longer than in previous specimens I have seen, being as long as the thecae measured along the outer curve.

Plumularia setacea (Hincks).

(For synonyms and references, see Farquhar, Trans. N.Z. Inst., vol. 28, p. 466; also Hilgendorf, Trans. N.Z. Inst., vol. 30, p. 214.)

Hab.—Timaru and Dunedin (New Zealand); Australia; Europe; Kermadec Islands (Denham Bay, Sunday Island).

This is a very delicate form of the species, and only about ¼ in. high.

Aglaophenia laxa Allman. Figs. 1, 2, 3.

A. laxa Allman, 1876, Journ. Linn. Soc. (Zool.), vol. 12, p. 275.

Hab.—New Zealand; Kermadec Islands (Denham Bay, Sunday Island).

This species seems never to have been seen since Allman found it thirty-four years ago in a collection brought home from New Zealand by Mr. Busk. Allman placed the specimen only provisionally in this genus, owing to his not having seen the corbulae. My specimen showed these structures, and a description is attached.

The whole specimen was creeping over a piece of sponge about 1 in. long and ½ in. wide. It is light brown in colour, and 1½ in. in height. The hydrocaulus is simple and sparingly branched, the sketch in fig. 2 showing the most elaborately branched hydrocaulus found. The corbulae are about as long as one of the pinnae springing from the hydrocaulus. Each corbula consists of a rachis, from which spring about 18 costae, those on one side of the rachis alternating with those on the other. The rachis is jointed for every costa. The costae are narrow, so that the corbula is an open basket closed only by the overfolding of the lateral projections from

the costae. These projections are poorly developed on the proximal two costae, and still more poorly on the distal two. Even on the medial costae the lateral projections are developed on only one side of the proximal portion of each costa, but on both sides of the medial and distal portions. The

FIG. 1.

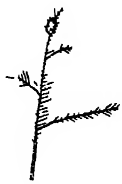

FIG. 2.

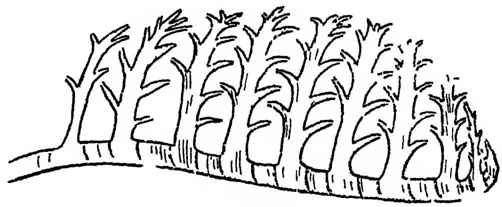

FIG. 3.

Fig. 1.—*Aglaophenia laxa;* magnified.
Fig. 2.— „ natural size.
Fig. 3.— „ corbula; magnified.

distal ends of the costae from one side of the rachis overlap the distal ends of those from the other side so as to close the corbulae above, and its extremity is closed by the upcurling of the distal end of the rachis. The specimen from which this description is taken is in the Canterbury Museum.

Aglaophenia ? x. Fig. 4.

This specimen is probably an *Aglaophenia*, but it is impossible to tell without the corbulae. I can find no previous description of any form like the one under consideration, and probably the species is new.

Trophosome.—Colony 90 mm. in height, sparingly branched: all the pinnae are in one plane, so that the whole colony is somewhat fan-shaped. The pinnae are alternate. Colour uniformly brown. Hydrocaulus with two not very distinct nodes to each hydrotheca, one opposite the base and one opposite the bend of the hydrotheca. Hydrothecae close together, not deeply inserted in the hydrocaulus, only slightly bent. The front wall of the hydrothecae bulges considerably below the origin of the intrathecal ridge. The thecostome has two teeth on each side, and none in back or front. The intrathecal ridge springs from only the outer side, and is inclined at about 45° to the hydrocaulus.

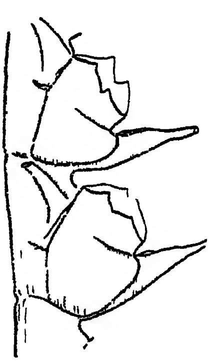

FIG. 4.
Aglaophenia ? x; magnified.

The mesial nematophore is very long, and projects for more than half its length clear away from the hydrotheca: it stands almost at right angles to the hydrocaulus; there are basal and terminal openings in this nematophore, but in the upper hydrotheca sketched on fig. 4 the basal opening has been obliterated by faulty drawing. The lateral nematophore is long and strongly bent backwards, reaching more than half-way back over the hydrocaulus.

Gonosome.—Not present.

Hab.—Denham Bay, Sunday Island, Kermadec Islands.

Type in Canterbury Museum, under the name of "*Aglaophenia? x.* Kermadec Islands." It is on the base of this specimen that *Synthecium elegans* is growing.

Aglaophenia ? y. Fig. 5.

This is probably another *Aglaophenia*, but, like the last, cannot be identified in the absence of the corbula. It also is probably new.

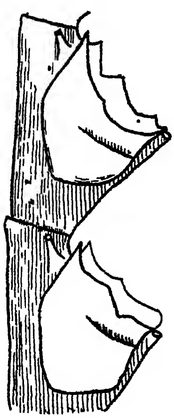

FIG. 5.
Aglaophenia? y; magnified.

Trophosome.—Colony 80 mm. in height, and probably more, as the specimen is obviously incomplete. The base of the hydrocaulus is 3–4 mm. in thickness, but it is incrusted by *Polyzoa* and the hydrothecae of an undistinguishable hydroid. Colour of the main stem dark brown, and of the pinnae light horn; the whole very much branched, giving a tangled mass of pinnae. The hydrocaulus bearing the hydrothecae is divided into very distinct nodes, one opposite the base of each hydrotheca. The hydrothecae are relatively far apart, almost globular, deeply inserted, and have a distinct bend in the middle; they are much lighter in colour than the hydrocaulus. The thecostome is widely open, and has three teeth on each side. The intrathecal ridge springs from the outer edge. The mesial nematophore is closely applied throughout to whole length to the front wall of the hydrotheca, and opens just at its lip. The lateral nematophores are short, and directed backwards; they do not reach to the node between the hydrothecae.

Gonosome.—Not present.

Hab.—Cast up on Denham Bay beach, Sunday Island, Kermadec Islands.

Type in the Canterbury Museum, under the name of "*Aglaophenia? y.* Kermadec Islands."

The following table shows the distribution of the species :—

	Kermadecs.	New Zealand.	Australia.	South Africa.	Europe.
Aglaophenia x ..	x	..	..	..	..
Aglaophenia y ..	x	..	..	..	..
Aglaophenia laxa ..	x	x	..	..	..
Synthecium elegans ..	x	x	..	..	..
Campanularia caliculata	x	x	x	..	..
Sertularia mininia ..	x	x	x	x	..
Plumularia setacea ..	x	x	x	..	x
Halecium tenellum ..	x	..	x	..	x

Art. XLIX.—*The* Crustacea *of the Kermadec Islands.*

By Charles Chilton, M.A., M.B., D.Sc., F.L.S., Professor of Biology, Canterbury College, University of New Zealand.

[*Read before the Philosophical Institute of Canterbury, 7th December, 1910.*]

The *Crustacea* described in this paper are mainly the result of collections made by Mr. W. R. B. Oliver and his companions during their stay on the Kermadec Islands in 1908, but included among them are several that had previously been collected at the islands by Captain Bollons, of the Government steamer "Hinemoa," and by him kindly handed over to me.

Mr. Oliver has very generously intrusted his whole collection to me for identification, and has supplied me with a number of notes on the occurrence, habits, &c., of many of the species, most of which are incorporated below. The collection proves to be a very representative one of the crustacean fauna of the islands, including marine and shore forms, and also the few land and fresh-water species that were to be obtained.

Altogether it comprises 83 species, grouped as follows: *Decapoda*, 47, *Euphausiacea*, 1; *Amphipoda*, 14; *Isopoda*, 10; *Cirripedia*, 4; *Ostracoda*, 2; *Branchiopoda*, 1; *Copepoda*, 4. It will be seen that although the majority of the species belong to the *Decapoda*, as comparatively little attention could be devoted to the smaller forms, still nearly all the other divisions of the *Crustacea* are represented. The identification of all the forms of the different groups has been a somewhat difficult task in the absence of any large collection of named specimens for comparison and of some of the necessary works of reference. I have endeavoured in all cases to indicate the description on which I have relied for the identification, and, when necessary, to state briefly the points in which my specimens appeared to differ.

A few *Crustacea* were obtained by the "Challenger" Expedition by means of dredgings in the neighbourhood of the Kermadecs, but so far as I am aware no previous collection has been made actually at the Kermadec Islands themselves, and it is therefore perhaps a little surprising that nearly all the specimens prove to belong to species already known. A few new species are described, but the proportion of these is very small considering that the collection comes from an absolutely new locality, and even some of these new species must be looked upon as confessions of ignorance. However gratifying it may be to describe new and peculiar forms, it is still more pleasing to find how completely the more conspicuous members of the crustacean fauna of the seas surrounding the Kermadecs are now known. This prepares the way for attacking questions of distribution. In this paper, however, I cannot enter fully into this matter, and can merely state that nearly all the marine and littoral species are Australian or Indo-Pacific forms, many of them being already known from the east coast of Australia, New Caledonia, Lord Howe Island, or Norfolk Island, though several are now recorded from this region for the first time. Comparatively few of the marine forms extend to New Zealand. The affinities

of the few land and fresh-water forms are somewhat indefinite, owing to the incompleteness of our knowledge of these forms from neighbouring lands, but on the whole they appear to show more connection with New Zealand than the marine forms do.

A few of the species from the Kermadecs are of especial interest—*e.g.*, the occurrence at these islands of the amphipod *Eurythenes gryllus* still further extends the distribution of this large amphipod, which has already attracted so much attention. It is perhaps worth while calling attention to the occurrence at the Kermadecs, and to the habits of *Actaeomorpha erosa*, *Cryptochirus coralliodytes*, and *Porcellanopagurus tridentatus*.

Sufficient information about the size, position, &c., of the Kermadecs will be found in the papers by Mr. W. R. B. Oliver* and Mr. R. Speight† in a previous volume of the Transactions. Mr. Oliver has dealt specially with the botany, while some of the groups of animals have been already investigated by Mr. Edgar R. Waite,‡ Professor W. B. Benham,§ Dr. F. W. Hilgendorf,|| Professor H. B. Kirk,¶ and Mr. T. Iredale.** It will be sufficient to state here that the Kermadecs form a group of four islands lying in a line extending from Sunday Island (lat. 29° 50′ S., long. 177° 59′ W.) to French Rock (lat. 31° 24′ S., long. 178° 51′ W.). The whole group lies about half-way between New Zealand and the Tonga Islands.

I have followed the classification given by Dr. W. T. Calman in his account of the *Crustacea* in Ray Lankester's "Treatise on Zoology," but as a matter of convenience I have placed the *Decapoda* first. Only those synonyms and references have been given that appear to be necessary.

My hearty thanks are due to Mr. Oliver for the opportunity of examining the collection, and for the thorough manner in which he collected and carefully recorded all the specimens available. I am also indebted to Professor Benham and Messrs. Waite and Hamilton for the loan of books from the libraries under their control.

LIST OF SPECIES.

Subclass MALACOSTRACA.

Order DECAPODA.

Suborder NATANTIA.

Plesionika spinipes Spence Bate.
Merhippolyte spinifrons (Milne-Edwards).
Alope palpalis White.
Rhynchocinetes rugulosus Stimpson.
Alpheus socialis Heller.
? *Arete dorsalis* Stimpson.
Synalpheus sp.
Betaeus sp.

* "The Vegetation of the Kermadec Islands," Trans. N.Z. Inst., vol. 42, p. 118.

† "Petrological Notes on Rocks from the Kermadec Islands," Trans. N.Z. Inst., 42, p. 241.

‡ "A List of Known Fishes of Kermadec and Norfolk Islands, and a Comparison with those of Lord Howe Island," Trans. N.Z. Inst., 42, p. 370.

§ "Stellerids and Echinids from the Kermadec Islands," Trans. N.Z. Inst., 43, p. 140.

|| "On some Calyptoblast Hydroids from the Kermadec Islands," Trans. N.Z. Inst., 43, p. 540.

¶ "The Sponges collected at the Kermadecs by Mr. Oliver," Trans. N.Z. Inst., 43, p. 574.

** "On Marine Mollusca from the Kermadec Islands," Proc. Mal. Soc., 9, pt. 1, p. 68 (March, 1910).

Suborder Reptantia.

Jasus hugelii (Heller).
Thenus orientalis Rumph.
Phyllosoma duperreyi Guérin.
Iconaxiopsis kermadecensis sp. nov.
Petrolisthes lamarckii var. *rufescens* (Heller).
Pachycheles lifuensis Borradaile.
Callianassa articulata Rathbun.
Upogebia danai (Miers).
Clibanarius striolatus Dana.
Calcinus imperialis Whitelegge.
Porcellanopagurus tridentatus Whitelegge.
Eupagurus sinuatus Stimpson.
Eupagurus hectori Filhol.
Albunea microps Miers.
Dromia unidentata Ruppell.
Ovalipes bipustulatus (Milne-Edwards)
Actaeomorpha erosa Miers.
Xantho nudipes (Dana).
Xanthodes lamarckii (Milne-Edwards).
Ozius lobatus Heller.
Trapezia ferruginea var. *areolata* Dana.
Chlorodopsis melanochira A. Milne-Edwards.
Banareia armata A. Milne-Edwards.
Pilumnus fimbriatus Milne-Edwards.
Eriphia norfolcensis Grant and McCulloch.
Lophactaea actaeoides A. Milne-Edwards.
Plagusia chabrus (Linn.).
Plagusia dentipes De Haan.
Plagusia tuberculata Lamarck.
Percnon pilimanus (A. Milne-Edwards).
Geograpsus grayi Milne-Edwards.
Leptograptus variegatus (Fabr.).
Cyclograpsus lavauxi Milne-Edwards.
Planes minutus (Linn.).
Ocypoda kuhlii De Haan.
? *Cryptochirus coralliodytes* Heller.
Halimus spinosus Hess.
Huenia proteus De Haan.
Schizophrys hilensis Rathbun.

Order EUPHAUSIACEA.

Thysanoessa gregaria G. O. Sars.

Order AMPHIPODA.

Nannonyx kidderi (Smith).
Eurythenes gryllus (Licht.).
Moera mastersii (Haswell).
Melita inaequistylis (Dana).
? *Melita palmata* (Montagu).
Aora typica Kröyer.
? *Orchestia gammarellus* (Pall.).
Parorchestia tenuis (Dana).
Parorchestia sylvicola (Dana).
Phrosina australis Stebbing.
Phronima novae-zealandiae Powell.
Platyscelus intermedius Thomson.
Oxycephalus clausi Bovallius.
Caprella acutifrons Latreille.

Order ISOPODA.

Rocinela orientalis Schiödte and Meinert.
Meinertia imbricata (Fabricius).
Nerocila macleayii (Leach).
Dynamenella huttoni (G. M. Thomson).
Cilicaea caniculata (Thomson).
Idotea metallica Bosc.
Ligia novae-zealandiae Dana.
Trichoniscus kermadecensis sp. nov.
Philoscia oliveri sp. nov.
Metoponorthus pruinosus (Brandt) [introduced].

Subclass CIRRIPEDIA.

Order THORACICA.

Lepas pectinata Spengler.
Lepas denticulata Gruvel.
Lepas anatifera Linnaeus.
Lepas fascicularis Ellis and Solander.

Subclass OSTRACODA.

Order PODOCOPA.

Cypridopsis minna (King). | *Ilyodromus smaragdinus* G. O. Sars.

Subclass BRANCHIOPODA.

Order CLADOCERA.

Daphnia thomsoni G. O. Sars.

Subclass COPEPODA.

Order EUCOPEPODA.

Cyclops sp.
Lepeophtheirus sp.
Pandarus sp.
Pontella sp.

Subclass MALACOSTRACA.

Order DECAPODA.

Suborder NATANTIA.

Plesionika spinipes Spence Bate.

Plesionika spinipes Spence Bate, Rep. Voy. "Challenger," 24, p. 646, pl. 113, fig. 2, 1888.

One specimen washed up on Terrace's Beach, Sunday Island.

It agrees well with Spence Bate's description and figures, except that the serrations on the underside of the rostrum are smaller than those shown in his figure. The "Challenger" specimens were dredged at a depth of 150 fathoms, at Station 219, north of New Guinea.

Merhippolyte spinifrons (Milne-Edwards).

Hippolyte spinifrons, Milne-Edwards, Hist. Nat., Crust., 2, p. 377, 1837; Miers, Cat. N.Z. Crust., p. 80, 1876. *Merhippolyte spinifrons* G. M. Thomson, Trans. Linn. Soc., Zool., 8, p. 444, 1903.

Four specimens from Meyer Island.

These specimens agree well with Milne-Edwards's description, except that there are 2 minute teeth on the underside of the rostrum near the apex. As Spence Bate has pointed out, it is probable that by the expression "les épines suborbitaires" Milne-Edwards meant not the short antennal tooth, but the long spine on the first segment of the peduncle of the antenna, and this corresponds to his description.

I cannot reconcile Filhol's description and figure with this species.* The figure distinctly shows a large supra-ocular spine, and looks as if it had been taken from a specimen of *Alope palpalis*, and his description is not inconsistent with this supposition.

Alope palpalis White.

Alope palpalis White, Proc. Zool. Soc., 1847, p. 124, 1847; Miers, Cat. N.Z. Crust., p. 84, 1876; Thomson, Trans. Linn. Soc. (2), Zool., 8, p. 440, pl. 28, figs. 3–12, 1903. ? *Alope australis* Baker, Trans. Roy. Soc. South Aust., 38, p. 154, pl. 30, figs. 1–7, 1904; McCulloch, Rec. Aust. Mus., 7, p. 313, 1909.

Numerous specimens from Coral Bay, Sunday Island, and from Meyer Island.

* Mission de l'île Campbell. p. 431, pl. 53, fig. 13.

The largest of these is about 33 mm. in length, and agrees well with the description of this species given by Thomson, the rostrum having 4 teeth, with a fairly wide interval between the second and third; the external maxillipeds are greatly developed. In the other specimens, most of which are considerably smaller, there appears to be considerable variation in the number of teeth on the rostrum: in one specimen 27 mm. long the rostrum bears 6 teeth, somewhat unequal in size and a little unequally spaced; in other specimens there are only 4, and the interval between the second and third varies in extent. Although none of the specimens are as large as those sometimes met with in New Zealand, I prefer to refer them to the same species. I am doubtful whether *Alope australis* Baker is really distinct from this species. According to Mr. McCulloch, *A. australis* is common near Sydney Harbour.

Rhynchocinetes rugulosus Stimpson.

Rhynchocinetes rugulosus Stimpson. Proc. Acad. Nat. Sci. Philad., 12, p. 36, 1860; McCulloch, Rec. Aust. Mus., 7, p. 310, pl. 79, figs. 1–8, 1909. *Rhynchocinetes typus* Miers, Cat. N.Z. Crust., p. 77, 1876.

Three specimens from rock-pools, Sunday Island (Captain Bollons, 1907); two smaller one from Meyer Island (W. R. B. Oliver).

My specimens agree well with the description and figures given by McCulloch, and, like his, differ from *R. typus* Milne-Edwards in having only about 6 teeth on the upper distal margin of the rostrum and 13 below. The other differences given by Miss Rathbun (quoted by McCulloch) are not very important, and some of them do not apply to my larger specimens, in which the maxillipeds are proportionately longer than in smaller specimens. In recording *R. typus* from Peru, Miss Rathbun (Proc. U.S. Nat. Mus., 38, p. 562) gives the length as 11 cm.; my largest specimen is about 5 cm. In larger specimens one would naturally expect the teeth on the rostrum to be more numerous; and even if such large specimens are not found in Australian seas (McCulloch does not give the size of his specimens) it seems probable that *R. typus* and *R. rugulosus* are local varieties of a species widely spread in the Southern Hemisphere.

The species was included among the New Zealand *Crustacea* by Miers under the name *R. typus*, on the authority of specimens in the British Museum collections, though I am not aware of any specimens from the main islands of New Zealand in local collections. It occurs at Sydney and at Lord Howe Island. Milne-Edwards's specimens of *R. typus* are from the Indian Ocean.

Alpheus socialis Heller.

Alpheus socialis Heller, Voy. "Novara," Crust., p. 106, pl. 10, fig. 1, 1865; Miers, Cat. N.Z. Crust., p. 82, 1876; G. M. Thomson, Trans. Linn. Soc., Zool., 8, p. 436, pl. 27, figs. 6–12, 1903.

Two specimens from under stones at low-water mark, Coral Bay, Sunday Island, collected by Mr. T. Iredale.

These two specimens agree well with the original description given by Heller, and I have no doubt they belong to the species described by him; they also agree fairly well with the more recent description given by Thomson, but it is possible, as Stebbing has already pointed out, that more than one species is included by him under this name. In one of my specimens the right cheliped is the larger, while in the other it is the left; Thomson

states that in the specimens examined by him it is always the left that is the larger. The largest of my specimens measures 22 mm. in length—*i.e.*, half the length given by Thomson for his largest specimen.

? Arete dorsalis Stimpson.

? *Arete dorsalis* Stimpson, Proc. Acad. Nat. Sci. Philad., 12, 1860; Coutière, Fauna and Geog. Maldive and Laccadive Archipelagoes, vol. 2, pt. iv, p. 866, 1904.

Three specimens from Coral Bay, Sunday Island.

These specimens are only provisionally referred to this species; they agree with the description given by Coutière in most respects, but differ in having the inner margin of the fixed finger regularly convex and without separate teeth, while the carpus of the smaller chelipeds is made up of 4 joints instead of the typical 3 found in this genus. The Kermadec specimens will therefore probably form a separate species, but in the meantime I prefer to leave them provisionally under the above name.

Arete dorsalis is found at Samoa, New Caledonia, Hong Kong, and at the Laccadives.

Synalpheus sp.

From Coral Bay and Meyer Island; several specimens.

Owing to want of some of the necessary works of reference these specimens have not yet been satisfactorily identified; they represent one, or perhaps two, species.

Betaeus sp.

Four specimens from Coral Bay, Sunday Island, collected by Mr. T. Iredale.

Not yet identified. The species to which these specimens belong is quite distinct from *Betaeus aequimanus* Dana, which occurs fairly commonly on the New Zealand coasts.

Suborder REPTANTIA.

Jasus hügelli (Heller).

Palinurus hugelii Heller, Reise der "Novara," Crust., p. 96, pl. 8, 1868; Haswell, Cat. Aust. Crust., p. 172, 1882. *Palinurus tumidus* Kirk, Trans. N.Z. Inst., 12, p. 314, 1879.

One small specimen from Sunday Island; the dried abdomen of another was found on the beach at Denham Island.

The species is common on the east coast of Australia, and is occasionally taken in the northern part of Auckland.

Thenus orientalis Rumph.

Thenus orientalis Rumph, Mus., pt. 2, fig. D; Haswell, Cat. Aust. Crust., p. 170, 1882; Spence Bate, Rep. Voy. "Challenger," 24, p. 66, 1888; Borradaile, Trans. Linn. Soc., Zool., 13, p. 261, 1910.

A specimen 40 mm. long with bilobed rostrum and a strong spine on the abdomen appears to belong to this species, but the descriptions that I have been able to consult are short and incomplete.

Phyllosoma duperreyi Guérin.

Phyllosoma duperreyi Milne-Edwards, Hist. Nat., Crust., 2, p. 485, 1837; Guérin-Méneville, Voy. de la "Coquille," p. 46, pl. 5, fig. 2, 1838; Stebbing, Willey's Zool. Results, pt. 5, p. 609, 1900.

One specimen of this larval form was "cast up on Denham Bay Beach. Sunday Island, 31st May, 1908."

It is 26 mm. long and 18 mm. broad, and agrees closely with the description and figures given in the "Voyage de la 'Coquille.'"

It is not certainly known to what adult form *Phyllosoma duperreyi* belongs, but Professor Haswell, in describing the *Phyllosoma* stage of *Ibacus peronii* Leach [I. *incisus* Péron], says that it is not unlikely that *Phyllosoma duperreyi* is an earlier stage in the development of the same animal (Proc. Linn. Soc. N.S.W., 4, p. 280). His specimen was obtained at Port Jackson; the original specimen of *P. duperreyi* was obtained at the same place; while the one described by Stebbing is from Milne Bay, New Guinea.

Iconaxiopsis kermadecensis sp. nov. Figs. 1 and 2.

In general resembling *I. andamanensis* Alcock, but apparently differing in the following points: The rostrum not quite reaching to the end of the second joint of the antennular peduncle, triangular, margins towards the apex smooth, but with a prominent tooth on each side at the base of the rostrum, a slight ridge being continued backwards on the carapace from each of these lateral teeth; slightly further back are 3 smaller teeth closely placed in a transverse row on the carapace, one central and two lateral,

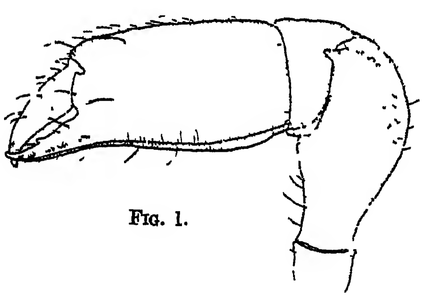

Fig. 1.

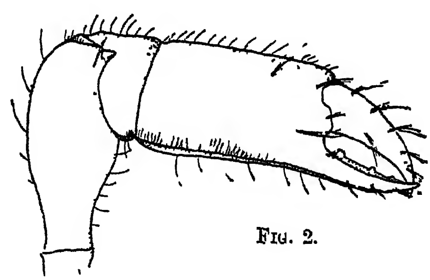

Fig. 2.

Iconaxiopsis kermadecensis.

Fig. 1. Left cheliped. Fig. 2. Right cheliped.

with slight indications of ridges extending backwards from them. There is a small tuft of long hairs on the inner side of the base of each lateral tooth at base of rostrum, other long hairs fringe the margins of the rostrum, and there are a few scattered hairs on the carapace and abdomen.

Eyes short, well pigmented.

The first pair of chelipeds large, longer than abdomen, the left slightly larger than the right, propod in each compressed, with numerous hairs on the upper margin and a well-marked fringe on the lower margin just above a slight ridge which extends almost to the end of the fixed finger, rest of surface smooth; both fingers sharply pointed; movable finger

without definite teeth; fixed finger with 2 small teeth, one near the base and the other, slightly larger, about the middle of the inner margin; on the right cheliped sometimes a third tooth nearer the apex of fixed finger.

Length of carapace in largest specimen, including rostrum, 17 mm.: length of abdomen to end of telson, 29 mm.

Several specimens from Meyer Island and Coral Bay; others from rock-pools at Sunday Island, collected by Captain Bollons.

I am unable to identify this species with any descriptions known to me, and therefore describe it provisionally as new; it may, however, prove to be identical with some of the species of *Axius* already described. I am a little uncertain if it is properly placed in *Iconaxiopsis*, but it seems to agree well with Alcock's description of this genus.

Petrolisthes lamarckii var. rufescens (Heller).

?*Porcellana dentata* M.-Edwards, Hist. Nat., Crust., 2, p. 251, 1837. *Petrolisthes dentatus* Haswell, Cat. Aust. Crust., p. 146, 1882. *Petrolisthes lamarckii* var. *rufescens* Borradaile, Proc. Zool. Soc., 1898, p. 464, 1898 (with synonymy). *Petrolisthes lamarcki* Grant and McCulloch, Proc. Linn. Soc. N.S.W., 31, p. 38, 1906.

Several specimens found under stones on Meyer Island; others from Coral Bay, Sunday Island, collected by Mr. T. Iredale.

These specimens appear undoubtedly to belong to this widespread and variable species as understood by Borradaile, and, on the whole, they agree pretty closely with the variety *rufescens*. In the larger specimens the merus of the walking-legs usually bears on the upper margin a series of minute spines, but in the smaller specimens these are hardly distinguishable. Borradaile suggests that this variety is possibly a distinct species.

Pachycheles lifuensis Borradaile.

Pachycheles lifuensis Borradaile, Willey's Zool. Results, p. 424, 1900; Grant and McCulloch, Proc. Linn. Soc. N.S.W., 32, p. 155, pl. 1, figs. 2, 2*a*, 1907.

Numerous specimens from Coral Bay, Sunday Island, and from Meyer Island.

These specimens seem undoubtedly the same as those from Norfolk Island examined by Grant and McCulloch, and they appear to have been rightly referred to *Pachycheles lifuensis*, originally described from Lifu, Royalty Islands. Mr. Borradaile describes the left cheliped as being the larger, but the series of specimens before me shows that either the right or the left may be the larger.

Callianassa articulata Rathbun.

Callianassa articulata Rathbun, Bull. U.S. Fish. Comm. for 1903, p. 892, 1906.

A single specimen from a rock-pool, Sunday Island, collected by Captain Bollons in 1907.

This agrees well with Miss Rathbun's description of this species from Hawaiian Islands specimens, except that the cornea does not occupy quite so much of the eye-stalk, occupying less than one-half instead of more than one-half. The specimen also is considerably larger than Miss Rathbun's, the carapace being 12 mm. long and the abdomen 40 mm., while

an ovigerous male of her specimens was 6·4 mm. in length of carapace, with the abdomen 16 mm. long.

I have to thank Mr. A. R. McCulloch, of the Australian Museum, for kindly comparing this species with Australian forms, and for suggesting that it belonged to *C. articulata* Rathbun.

Upogebia danai (Miers).

Gebia danai, Miers, Ann. Mag. Nat. Hist., ser. 4, 17, p. 323, 1876; and Cat. N.Z. Crust., p. 70, 1876. *Upogebia danai*, Chilton, Trans. N.Z. Inst., 39, p. 460, 1907.

Two small specimens taken on rocks at low tide, Coral Bay, Sunday Island, by Mr. T. Iredale.

Clibanarius striolatus Dana.

Clibanarius striolatus Dana, U.S. Expl. Exped., Crust., pt. 1, p. 463, pl. 29, fig. 3 *a–c*, 1852; Haswell, Cat. Aust. Crust., p. 159, 1882; Alcock, Cat. Indian Decap. Crust., pt. 2, Anomura, p. 46, pl. 4, fig. 7, 1905 (with synonymy).

Two specimens collected by Mr. Roy Bell, and handed by him to Mr. Oliver.

They agree fairly well with the description and figure given by Alcock, and must, I think, belong to this species; the chelipeds are more spinituberculate than is shown in his figure, and in this respect appear to agree with the specimens from Port Denison referred to this species by Haswell. The rostrum is very short, and forms only a very slight projection, broadly rounded at the end.

Alcock gives the distribution of this species as follows: "Gulf of Aden and Seychelles eastwards to Tahiti; from about 43° E. eastwards to about 150° W., and from about 28° N. to about 18° S." Its occurrence at the Kermadecs extends the southern limit to about 30° S.

Calcinus imperialis Whitelegge.

Calcinus imperialis Whitelegge, Rec. Aust. Mus., 4, p. 48, pl. 9, 1901; Alcock, Cat. Indian Dec. Crust., pt. 2, Anomura, p. 164, 1905; Grant and McCulloch, Proc. Linn. Soc. N.S.W., 32, p. 154, 1907.

Several specimens among rocks at Meyer Island, inhabiting shells of *Delphinula*, *Lotorium*, and *Gyrineum*; also one from Sunday Island (Captain Bollons).

The species is common at Norfolk and Lord Howe Islands, and has also been found on the coast of Australia, near Sydney.

Porcellanopagurus tridentatus Whitelegge.

Porcellanopagurus tridentatus Whitelegge, Mem. Aust. Mus., 4, p. 181, figs. 13, 13*a*, 13*b*, 1900.

Five specimens from Meyer Island and Sunday Island.

These specimens must, I think, be referred to Whitelegge's species, although naturally they differ in some minute points from his long detailed description. The anterior spine on the lateral margin of the carapace is very well marked in some specimens, but the posterior tooth is almost

or quite obsolete, the short prominence, however, being noticeable. The upper margin of the larger (right) cheliped is more even than is shown in Whitelegge's figure. The chelipeds are unequal in both sexes.

This hermit-crab is somewhat peculiar in its habits: it was found by Mr. Oliver under stones between tide-marks, and he states that it was not common, and that it never uses a spiral shell, but manages to keep on its back a single valve of a bivalve mollusc's shell or a vacant *Siphonaria* or limpet shell.

Only three species of this peculiar genus are as yet known—viz., *P. edwardsi*, from Campbell Island and the Snares; the present species; and *P. platei*, from Juan Fernandez. The description of this latter species I have not yet been able to obtain. Mr. Whitelegge's specimens were dredged in 54–59 fathoms, off the coast of New South Wales, and the species to which they belong is much smaller than *P. edwardsi*, and appears to differ also in having the chelipeds unequal in the female, while in the female of *P. edwardsi*, according to Filhol, the chelipeds are small and subequal.

Eupagurus sinuatus Stimpson.

Eupagurus sinuatus Stimpson, Proc. Acad. Nat. Sci. Philad., 10, p. 348, 1864; Haswell, Cat. Aust. Mus., p. 153, 1882; Alcock, Cat. Indian Decap. Crust., pt. 2, Anomura, p. 175, 1905.

Three specimens from Meyer Island seem to belong to this species. They agree fairly well with the short description quoted by Haswell, especially in having the merus of the chelipeds deeply excavated below, the margins provided with long cilia, and external margins spinose: the carpus, however, does not show much trace of a smooth median line, and the median series of spines on the propod is not well marked.

The species has been recorded from Port Jackson, Australia.

Eupagurus hectori Filhol.*

Eupagurus hectori Filhol, Mission de l'île Campbell, p. 419, pl. 51, fig. 1, 1885; Thomson, Trans. N.Z. Inst., 31, p. 177, 1899; Lenz, Zool. Jahr., 14, p. 447, 1901; Alcock, Cat. Indian Decap. Crust., pt. 2, Anomura, p. 176, 1905.

Numerous specimens from Meyer Island, and from Coral Bay, Sunday Island, living in shells of various gastropods. These agree closely with Filhol's description, and can be readily distinguished from other New Zealand species by the glabrous chelipeds. The chelipeds and the greater part of the ambulatory legs in spirit specimens are coloured red.

Filhol states that this species becomes more abundant to the south of New Zealand, especially in Stewart Island; Thomson records it from Stewart Island, and Lenz from D'Urville Island, and I have recently received a specimen from Miss Shand from Chatham Islands.

* I have also from Meyer Island several specimens of a small hermit-crab which in general resembles *Eupagurus*, but has the abdomen straight, though soft, and the telson and uropoda symmetrical. A fuller description is held over in the meantime, as I am not sure of the systematic position of the species.

Albunea microps Miers.

Albunea microps Miers, Jour. Linn. Soc., Zool., 14, p. 328, pl. 5, figs. 12, 13, 1877; Henderson, Rep. Voy. "Challenger," 17, p. 40, 1888; Borradaile, Willey's Zool. Results, pt. 4, p. 126, 1900.

One small specimen from Meyer Island (12 fathoms), agreeing well with Miers's description.

The species is recorded by Miers from Sooloo Island, and was taken by the "Challenger" at Station 212 in the Celebes Sea; more recently Borradaile has recorded it from Blanche Bay, New Britain.

Dromia unidentata Ruppell.

Dromia unidentata Ruppell, 24 Krabben roth. Meer., p. 16, pl. 4, fig. 2; pl. 6, fig. 9; 1830: Alcock, Cat. Indian Dec. Crust., pt. 1, Brachyura, p. 47, pl. 2, fig. 6, 1901.

One specimen taken on coral below low-water mark, Meyer Island; the hinder portion of the carapace covered with what appears to be the dried remains of a compound Ascidian.

This agrees closely with the description and figure given by Alcock.

The species is widely distributed in the Indian Ocean and the Malay Archipelago, but does not appear to have been recorded from Australian seas.

Ovalipes bipustulatus (Milne-Edwards).

Platyonichus bipustulatus M.-Edwards, Hist. Nat., Crust., 1, p. 437, pl. 17, figs. 7–10, 1834; Miers, Cat. N.Z. Crust., p. 32, 1876. *Ovalipes trimaculatus* Stebbing, South African Crustacea, pt. 2, p. 13, 1902; Doflein, Wiss. Ergebn. Deutschen Tiefsee Exped., 1898–99, p. 92, pl. 32, fig. 6, 1904; Fulton and Grant, Proc. Roy. Soc. Victoria, 19, pt. 1, p. 18, 1906. *Ovalipes bipustulatus*, M. J. Rathbun, Proc. U.S. Nat. Mus., 38, p. 577, 1910.

Several small specimens from Sunday Island, collected by Mr. Oliver, and one by Captain Bollons.

Mr. Oliver says that all the specimens collected were picked up dead on the beaches, and that apparently they live just below low-water mark. In connection with this, it is worth while mentioning that in March, 1888, Mr. R. Helms, of Greymouth, sent me specimens of this species that he had obtained at Greymouth whilst digging in the sand at low-water mark during spring tides for pipis (*Mesodesma spissa*), and he stated that the animal appeared to use the hind legs for digging in the sand more than for swimming, and that it buried itself in a remarkably short time. He added, "The colour of this animal is very fine; the carapace is light grey, almost lavender, and the joints of the arms bright red, tinging near the claws to dark orange."

The habits of *Platyonichus ocellatus* Herbst, as described by Verrill and Smith, seem to be closely similar. (See Stebbing, Hist. Crustacea, p. 67.)

The species is very widely distributed in the Southern Hemisphere, and extends also to Japan.

Actaeomorpha erosa Miers.

Actaeomorpha erosa Miers, Jour. Linn. Soc., Zool., 13, p. 1, pl. 14, 1883.

Several specimens from Coral Bay, Sunday Island, and from Meyer Island, on coral; some dredged in 12 fathoms.

These specimens agree minutely with Miers's description, drawn up from a single specimen dredged in 7 fathoms in Port Curtis, Australia. Some of the specimens have the dorsal surface variously marked with red, and this, together with the granulated nature of the surface, gives them the appearance of small pieces of coral.

Xantho nudipes (Dana).

Chlorodius nudipes Dana, Proc. Acad. Nat. Sci. Philad., 1852, p. 79, 1852; and U.S. Expl. Exped., Crust., 1, p. 209, pl. 11, figs. 12 *a–c*, 1855. *Leptodius nudipes* A. Milne-Edwards, Nouv. Archiv. Mus., 9, p. 225, pl. 7, fig. 5, 1873; Miers, Cat. N.Z. Crust., p. 17, 1876; Filhol, Mission de l'île Campbell, p. 374, 1885. *Xantho* (*Leptodius*) *nudipes* Alcock, Proc. Asiatic Soc. Bengal, 67, p. 121, 1898.

Numerous specimens from Coral Bay, Sunday Island; Meyer Island, &c.

It is only with considerable hesitation that I assign these specimens to this species. In the rugose and wrinkled character of the hands of the chelipeds, and in the general appearance of the carapace, the short legs almost destitute of setae, &c., they appear to agree pretty closely with the description and figures given by A. Milne-Edwards, except that he describes the antero-lateral margins of the carapace as being divided into 10 or 12 teeth, grouped in 4 lobes. In my specimens the teeth are much fewer in number, the two posterior ones being simple and of the usual character, while anterior to these the lobes or teeth become somewhat indefinite, so that the anterior border might be described as being divided into 6 to 8 teeth. Alcock says, "The antero-lateral border is divided into 4 acute lobes or teeth, but each of the first 3 teeth have, at base, either one or two (one on either side) small additional cusps, and the 4th tooth is generally double, so that altogether there are from 8 to 11 teeth on the antero-lateral margin." This would agree moderately well with my specimens, except that in them none of the lobes or teeth are quite acute. On the other hand, Alcock places the species under the subgenus *Leptodius*, and specially mentions that "the fingers are typical spoons," and, so far as one can judge from the figure, this appears to be the case with the specimens figured by Dana. In my specimens the fingers are quite sharp at the points, and this seems to be the case with those figured by A. Milne-Edwards. Consequently, while I feel pretty confident that my specimens must belong to the same species as those described by Milne-Edwards from New Caledonia, I am doubtful if they are quite the same as those described by Alcock.

X. nudipes and the allied species *Chlorodius eudorus* Milne-Edwards are stated to occur in New Zealand on the authority of specimens in the collections of the Paris Museum; Filhol says that the specimens of *X. nudipes* come from Cook Strait, and he considers that *Chlorodius eudorus* should be looked upon as a variety of this species. I have seen no specimens from New Zealand itself that could be referred to either of these species.

Xantho (*Leptodius*) *euglyptus* Alcock, from Galle and Mergui, and *Xantho quinquedentatus* Krauss, from South Africa, both seem to be closely similar

to *X. nudipes*, and the latter species is, according to Alcock, described and figured as having sharp fingers.

Considering the difficulty of determining species in this group, and the fact that I have no large series of specimens for comparison, the reference of my specimens from the Kermadecs to *X. nudipes* must be looked upon as provisional only.

Xanthodes lamarckii (Milne-Edwards).

Xantho lamarckii Milne-Edwards, Hist. Nat., Crust., 1, p. 391, 1831. *Xanthodes lamarckii* Whitelegge, Mem. Aust. Mus., 3, p. 130, 1897; Alcock, Proc. Asiatic Soc. Bengal, 67, p. 157, 1898.

Several specimens, male and female, from Coral Bay, Sunday Island, collected by Mr. T. Iredale.

These specimens agree closely with the description given by Alcock; the females have the abdomen fringed with long hairs, as described by Whitelegge.

The species is widely distributed in the Indo-Pacific region.

Ozius lobatus Heller.

Ozius lobatus Heller, Reise der "Novara," Crust., p. 21, pl. 2, fig. 4, 1868; Haswell, Cat. Aust. Crust., p. 63, 1882.

Three specimens, two males and one female. Mr. Oliver says this species is fairly common among rocks between tide-marks.

The specimens that I have been able to examine agree minutely with Heller's description. The species is undoubtedly very closely allied to *O. truncatus* Milne-Edwards; but, as Heller points out, that species, according to the description and figures by Milne-Edwards and Dana, appears to have the front almost straight, while in *O. lobatus* it is divided into 4 lobes; the two inner ones are broad and rounded and the two outer ones are narrower and rather more prominent, being similar to the small rounded lobe at the inner angle of the orbit.

O. lobatus and *O. truncatus* are both recorded from Australia, and *O. truncatus* has also been found in New Zealand. The occurrence of *O. lobatus* at the Kermadecs renders it still more probable that the two species are identical, but a comparison of typical specimens is desirable before the two are combined.

Trapezia ferruginea var. areolata Dana.

Trapezia areolata Dana, Proc. Acad. Nat. Sci. Philad., 1852, p. 83, 1852; and U.S. Expl. Exped., Crust., 1, p. 259, pl. 15, figs. 8 *a–b* and 9, 1853. *T. areolata* var. *inermis* A. Milne-Edwards, Nouv. Archiv. Mus., 9, p. 259, pl. 10, fig. 6, 1873. *T. ferruginea* var. *areolata* Alcock, Journ. Asiatic Soc. Bengal, 67, p. 221, 1898.

One female specimen (both chelipeds missing) from Meyer Island, found on coral, 1 fathom. The honeycomb network of fine brown lines on the carapace is still very plainly marked in the spirit specimen.

The species is widely distributed in Indo-Pacific seas.

Chlorodopsis melanochira A. Milne-Edwards.

Chlorodopis melanochirus A. Milne-Edwards, Nouv. Archiv. Mus., 9, p. 228, pl. 8, fig. 5, 1873; Haswell, Cat. Aust. Crust., p. 55, 1882. *Chlorodopsis melanochira* Alcock, Journ. Asiatic Soc. Bengal, 67, p. 168, 1898.

Numerous specimens from Coral Bay, Sunday Island, and from Meyer Island.

These agree very closely with the descriptions and figures given by Milne-Edwards and Alcock, except that the dark coloration of the fixed finger does not extend along the lower border of the hand. In this character they resemble *C. melanodactylus*, but they distinctly differ from that species in having the antero-lateral margin "divided into four lobes, each of which is crowned with several spinules."

The species is known from the Andamans, the coasts of Australia, and from New Caledonia.

Banareia armata A. Milne-Edwards.

Banareia armata A. Milne-Edwards, Ann. Soc. Ent. Fr. (4), 9, p. 168, pl. 8, 1869; and Nouv. Archiv. Mus., 9, p. 193, 1873: Alcock, Journ. Asiatic Soc. Bengal, 67, p. 153, 1898.

One specimen (dried) from Meyer Island, and two small spirit specimens from Coral Bay, Sunday Island. The hands of the chelipeds and the joints of the legs are more granular than is shown in Milne-Edwards's figure, but the specimen agrees closely with Alcock's description, and must, I think, belong here.

The species is known to occur at New Caledonia and at the Andamans.

Pilumnus fimbriatus Milne-Edwards.

Pilumnus fimbriatus Milne-Edwards, Hist. Nat., Crust., 1, p. 416, 1834; Haswell, Cat. Aust. Crust., p. 66, pl. 1, fig. 4, 1882.

One specimen taken at low tide at Coral Bay, Sunday Island, by Mr. T. Iredale; another (dried) one from Meyer Island. They agree well with the descriptions given by Milne-Edwards and Haswell.

The species is known from the east coast of Australia.

Eriphia norfolcensis Grant and McCulloch.

Eriphia norfolcensis Grant and McCulloch, Proc. Linn. Soc. N.S.W., 32, pt. 1, p. 151, pl. 1, figs. 1, 1*a*, 1*b*, 1907.

Numerous specimens from Coral Bay, Sunday Island, and from Meyer Island, found under stones at low tide.

The species is common at Norfolk Island, where it is said to be known as the "poison crab."

Lophactaea actaeoides A. Milne-Edwards.

Lophactaea actaeoides A. Milne-Edwards, Nouv. Archiv. Mus., 9, p. 189, pl. 6, fig. 7, 1873.

One specimen from rock-pool, Meyer Island. It agrees well with Milne-Edwards's description and figure.

The species is found at New Caledonia, and I have a specimen from Norfolk Island also.

Plagusia chabrus (Linn.).

Cancer chabrus Linn., Syst. Nat., ed. 10, p. 628, 1758. *Plagusia capensis* De Haan, Faun. Japon., Crust., p. 58, 1835; Fulton and Grant, Proc. Roy. Soc. Victoria, 19, pt. 1, p. 20, 1906; Stebbing, South African Crustacea, pt. 3, p. 47 (with synonymy and critical remarks), 1905. *Plagusia chabrus* Miers, Cat. N.Z. Crust., p. 45, 1876, and Ann. Mag. Nat. Hist., ser. 5, 1, p. 152, 1878; Rathbun, Proc. U.S. Nat. Mus., 38, p. 591, 1910; Stebbing, Annals South African Mus., 6, p. 322, 1910 (with further synonymy).

One female specimen from Sunday Island. Mr. Oliver notes that only one specimen was seen during his stay on the island.

The species is widely distributed, and has been recorded from the Cape of Good Hope, Australia, Tasmania, New Zealand, &c.

In his latest work, Stebbing, in deference to the opinions of others, adopts the name *Plagusia chabrus* (Linn.) for this species, though he had previously argued in favour of *P. capensis* De Haan. I am glad that it is possible to retain the name by which the species has always been known in New Zealand.

Plagusia dentipes De Haan.

Grapsus (*Plagusia*) *dentipes* De Haan, Faun. Japon., Crust. decas, 2, p. 58, pl. 8, fig. 1, 1835. *Plagusia dentipes* Miers, Ann. Mag. Nat. Hist., ser. 5, 1, p. 152, 1878; Grant and McCulloch, Proc. Linn. Soc. N.S.W., 32, pt. 1, p. 153, 1907.

One male specimen, collected on the rocks between tide-marks, Sunday Island.

This species is closely allied to the preceding one, but can readily be distinguished by the spine on the lower distal angle of the merus in the walking-legs and by the presence of a few small tubercles on the carapace. The other differences pointed out by Grant and McCulloch seem hardly to apply in my specimens; thus, there is little difference between the front in the two, and both have the whole carapace equally covered with short hairs.

Plagusia dentipes is common on Norfolk Island and also on Lord Howe Island, but it has not been recorded from the main islands of New Zealand.

Plagusia tuberculata Lamarck.

Plagusia tuberculata Miers, Ann. Mag. Nat. Hist., ser. 5, 1. p. 148, 1878; Lenz, Zool. Jahrb., 14, heft 5, p. 473, 1901; Rathbun, Proc. U.S. Nat. Mus., 38, p. 590, 1910. *Plagusia depressa tuberculata* Rathbun, Bull. U.S. Fish. Comm. for 1903, p. 841, 1906. *Plagusia depressa* var. *squamosa* Grant and McCulloch, Proc. Linn. Soc. N.S.W., 32, p. 154, 1907.

Three females from Sunday Island.

Widely distributed in Indo-Pacific region. Recorded from Hawaiian Islands by Miss Rathbun, from Norfolk Island by Grant and McCulloch, and from "Lower California to Chile" by Miss Rathbun.

Percnon pilimanus (A. Milne-Edwards).

Acanthopus pilimanus A. M.-Edwards, Nouv. Archiv. Mus., 9. p. 300, pl. 14, fig. 5, 1873. *Leiolophus pilimanus* Miers, Ann. Mag. Nat. Hist., ser. 5, 1, p. 154, 1878. *Percnon pilimanus* Rathbun. Bull. U.S. Fish. Comm. for 1903, p. 842, 1906.

Two males and several females from Sunday Island.

These specimens agree very closely indeed with Milne-Edwards's description, except that there is no large tuft of fine hairs on the propod of the chelipeds; a well-marked tuft is, however, present on the merus of the larger male. The width of the abdomen of the larger male at the base is just equal to that of its length to the base of the last segment; in the smaller male the width is rather greater than this.

It is possible that these specimens should be referred to *P. planissimus*, but I assign them to *P. pilimanus* owing to the slightly narrower abdomen, the spines on the inner margins of the antennulary cavities, and to the fact that they agree minutely with Milne-Edwards's description and figure except as regards the hairs on the propod of the chelipeds. The smaller specimens agree well with the description of *P. planissimus* given by Alcock (Journ. Asiatic Soc. Bengal, 69, p. 439), except that the second row of spinules on the merus of the legs is well marked on the third legs as well as on the first and second; in the larger specimens the row is also indistinctly marked on the fourth. Miss Rathbun records both species from the Hawaiian Islands without comment.

Milne-Edwards states that the hairs on the chelipeds act as a sponge to maintain the humidity at the orifice of the branchial chamber. He had, however, seen only one male specimen, and, as the tuft on the merus is very small or quite absent in my female specimens, it seems more likely that the hairs may be a sexual character, developed in the adult male only, and in that case may not yet be fully developed in the two males in my possession. The females resemble the male except in the much smaller size of the chelipeds, which are much shorter and have the propod only slightly widened. The merus bears only a very small tuft of hairs in the larger female specimens, and none in the smaller specimens. It seems likely, therefore, that the tufts of fine hairs on the merus and propod are a secondary sexual character, developed only in large males, or perhaps only during the breeding season; they were evidently not present in the adult males of *P. planissimus* examined by Alcock, for he makes no mention of them. If, as seems likely, the other characters—*i.e.*, the narrower abdomen and the spines on the inner margin of the antennulary cavities—do not prove to be constant, one would be tempted to suggest that *P. planissimus* and *P. pilimanus* form one species, in which the males may develop the tufts of fine hairs on the chelipeds at certain seasons only.

Male: Width of carapace, 29 mm.; length, 32 mm.: total length of propod of cheliped, 15 mm.; width, 11 mm. Largest female: Width of carapace, 28 mm.; length, 31 mm.: total length of propod of cheliped, 8 mm.; width, 6 mm.

Mr. Oliver makes the following observations on the habits of this species: "Fairly common among rocks near low-tide mark. Very quick in its habits. Its colour somewhat resembles the rock, on which it stays perfectly still, but when any one approaches too near it darts into the water. When, after continued westerly winds, sand was driven ashore so as to bury the boulders on the north coast of Sunday Island to about half-tide

mark, thousands of these crabs, retreating before the encroaching sand, congregated in heaps among the rocks near shore until the sand was washed away again."

Geograpsus grayi (Milne-Edwards).

Grapsus grayi M.-Edwards, Ann. Sci. Nat. (3^e ser.), 20, p. 170, 1853; Haswell, Cat. Aust. Crust., p. 98, 1882. *Geograpsus grayi* A. Milne-Edwards, Nouv. Archiv. Mus., 9, p. 288, pl. 16, fig. 1.

One male and one female, agreeing well with Milne-Edwards's description.

The species is widely distributed in Australia, New Caledonia, Mauritius, Madagascar, &c.

Mr. Oliver makes the following remarks on the habits of this crab, which is almost terrestrial in habit: "This land-crab occurs sparingly on the east coast of Sunday Island, and more commonly on Meyer Island and other islets of the Herald Group. They make burrows little more in diameter than the width of their bodies, and 6–20 in. long. Often, however, they are content with merely digging their way under a stone lying on the surface. I have never found more than one crab in each burrow. Their burrows are found in the forest at Coral Bay more than 100 yards from the sea. The presence of shells and pieces of coral high up on Napier Islet can only be accounted for by supposing these crustaceans carried them there, but for what purpose it is difficult to imagine. Mr. Roy Bell tells me that land-crabs are in the habit of carrying shells from the rocks up to where they make their burrows."

Leptograptus variegatus (Fabr.).

Cancer variegatus Fabr., Ent. Syst., 2, p. 450, 1793. *Grapsus variegatus* Miers, Cat. N.Z. Crust., p. 36, 1876. *Leptograpsus variegatus* Fulton and Grant, Proc. Roy. Soc. Victoria, 19, pt. 1, p. 19, 1906; M. J. Rathbun, Proc. U.S. Nat. Mus., 38, pp. 547 and 588, 1910.

Several specimens were taken at Sunday Island. The Canterbury Museum collections also include one from the Kermadecs.

In Miers's catalogue it is included in the New Zealand fauna on specimens in the collections of the British Museum, but I do not know from what particular locality they were collected.

The species is found on the coasts of Peru and Chile, at Juan Fernandez, Australia, and other parts of the Southern Hemisphere.

Cyclograpsus lavauxi (Milne-Edwards).

Cyclograpsus lavauxi and *Cyclograpsus whitei* M.-Edwards, Ann. Sci. Nat. (3^e ser.), 20, p. 197, 1853. *Cyclograpsus lavauxi* Miers, Cat. N.Z. Crust., p. 41, 1876. *Cyclograpsus audouinii* Dana, U.S. Explor. Exped., Crust., 1, p. 359, pl. 22, fig. 2, 1852.

Three spirit specimens washed up on Low Flat Beach, Sunday Island; also two dried specimens in logs washed up on the beaches, Sunday Island.

The species is common on New Zealand coasts, and is also found in Australia.

I follow Miers in referring our New Zealand form to this species, and in considering *C. whitei* as identical with *C. lavauxi*. Other closely allied

species are recorded from South Africa, the Indian Ocean, New Guinea, Tasmania, &c., and a careful review of the genus is desirable.

Planes minutus (Linn.).

Cancer minutus Linn., Syst. Nat., ed. 12, p. 1048, 1766. *Planes minutus* Miers, Cat. N.Z. Crust., p. 39, 1876; M. J. Rathbun, Proc. U.S. Nat. Mus., 38, p. 589, 1910; Stebbing, South African Crustacea, pt. 3, p. 43, 1905, and pt. 5, p. 320, 1910.

Several specimens washed up on Denham Bay Beach, Sunday Island, in October, 1908.

The species is pelagic in habit, and is very widely distributed in tropical and temperate seas. Specimens from New Zealand are in the British Museum collections.

Ocypoda kuhlii De Haan.

Ocypoda kuhlii Miers, Ann. Mag. Nat. Hist., ser. 5, 10, p. 384, 1882; Miers, Collection H.M.S. "Alert," p. 237, 1884.

Several specimens from Sunday Island seem to belong to this species as described by Miers. The carapace is evenly granulated throughout, as in some of the specimens examined by Miers. Specimens were obtained at Thursday Island during the cruise of the "Alert," and the species is known from other parts of Australia, and is also widely distributed elsewhere.

? Cryptochirus coralliodytes Heller.

? Cryptochirus coralliodytes Heller, S. B. Akad. Wien., 41 (1), p. 366, pl. 2, figs. 33–39, 1861; Grant and McCulloch, Proc. Linn. Soc. N.S.W., 1906, pt. 1, pp. 7 and 33, 1906; Calman, Trans. Linn. Soc., Zool., 8, p. 47, 1900.

Several female specimens from Meyer Island "in brain-coral, 2 fathoms"; also two or three small male specimens among other *Crustacea* from Coral Island.

The males are much smaller than the females, and are less modified from the normal Brachyuran type—just as is the case in *C. dimorphus* Henderson.*

Of the Meyer Island specimens Mr. Oliver says, "Lives in a perfectly circular hole bored in living brain-coral."

In general appearance and mode of life these specimens evidently closely resemble this species, but I have no means of consulting Heller's description.

Mr. McCulloch has kindly compared a specimen from the Kermadecs with those collected off the coast of Queensland by himself and referred to this species, and finds that they are identical. He states, however, that he is doubtful if these specimens should really be referred to *C. coralliodytes*, as they appear to differ in certain points, and he suggests that they probably form a new species, distinct also from *C. dimorphus* Henderson, from the Andaman Island. I postpone consideration of this question till I can consult Heller's description of *C. coralliodytes*.

* Ann. Mag. Nat. Hist., ser. 7, 18, p. 214, 1906.

Halimus spinosus Hess.

Halimus spinosus Hess, Archiv. fur Nat., 1865, p. 129, pl. 6, fig. 1, 1865; Haswell, Cat. Aust. Crust., p. 6, 1882; McCulloch, Rec. Aust. Mus., 7, p. 53, 1908. *Halimus truncatipes* Miers, Ann. Mag. Nat. Hist., ser. 5, 4, p. 3, 1879; Baker, Trans. Roy. Soc. S.Aust., 29, p. 120, pl. 22, figs. 2, 2*a*, 1905.

One male with carapace 27 mm. long from rock-pools, Sunday Island (Captain Bollons); two smaller males from Meyer Island (W. R. B. Oliver); and one female with carapace 23 mm. long from Coral Bay, Sunday Island (T. Iredale).

These specimens agree closely with the description given by Miers for *H. truncatipes*, and undoubtedly belong to the same species as the specimen described by him; they also agree with the short description of *H. spinosus* given by Hess as quoted by Haswell, and I follow Haswell in considering these two species probably identical. According to Miers, *H. truncatipes* differs from *H. spinosus* by the much more squarely truncated joints of the ambulatory legs. In my female specimen, and particularly in the very small male specimen, these joints are less squarely truncated than in the large male, and the character is doubtless one that varies with the age of the specimen. The tubercles on the carapace agree very closely with the description given by Miers, and nearly all of them bear a number of yellow hooked or curved hairs. These are mentioned by Hess, but not by Miers, who only says that the legs are clothed with long fulvous hairs. In a dried specimen nearly all these hairs came away with the seaweeds when these were removed to expose the surface of the carapace. The median spine on the posterior margin of the carapace is moderately well marked in the female, but in the male is represented only by a small tubercle tipped with yellow hairs. Miers describes the chelipeds in the male as small; in my specimens they are somewhat swollen and smooth, with the fingers meeting only at the tip when closed, as in *H. laevis* Haswell. Both specimens bear on the carapace a number of seaweeds held by the curved hairs.

[I had written the above before I noticed that Mr. McCulloch had come to the same conclusion as to the identity of these two species and that Mr. Baker also concurred after comparing Sydney specimens with those at first referred by him to *H. truncatipes*.]

Huenia proteus De Haan.

Maja (Huenia) proteus De Haan, Faun. Japon., Crust., p. 95, pl. 23, figs. 4–6, 1839. *Huenia proteus* Haswell, Cat. Aust. Crust., p. 9, 1882; Alcock, Journ. Asiatic Soc. Bengal, 64, p. 195, 1895; Miers, Coll. H.M.S. "Alert," p. 191, 1884.

One small specimen, 5 mm. long, from Meyer Island, 12 fathoms, appears to be an immature female of this species.

The species ranges from Japan and China southwards to the eastern coast of Australia, and is also found at the Andamans, in the Indian Ocean.

Schizophrys hilensis Rathbun.

Schizophrys hilensis Rathbun, Bull. U.S. Fish. Commission for 1903, pt. 3, p. 882, fig. 38, 1906.

I have several specimens from Coral Bay, Sunday Island, and from Meyer Island, which must, I think, be referred to this species. They agree

with Miss Rathbun's description in having no accessory spines on the rostrum; the superocular eave thick, projecting at its posterior angle into a sharp tooth; the post-ocular spine simple; in having two spines on the posterior margin of the carapace; and in most of the other characters. The carapace, however, appears smoother than in Miss Rathbun's specimens, and in the central part the spines mentioned by her are either absent altogether or indicated only by slight tubercles; the two cardiac spines and the intestinal spine are thus indicated in some specimens, but there seems no indication whatever of the three gastric spines. My largest specimen has the carapace from the tip of the rostral spines to the extremity of the spines on the posterior margin 17 mm. in length, and the width without spines 10 mm., thus corresponding with the dimensions given by Miss Rathbun. Her specimens are from the Hawaiian Islands.

Order EUPHAUSIACEA.

Thysanoessa gregaria G. O. Sars.

Thysanoessa gregaria G. O. Sars, Rep. Voy. "Challenger." 13, p. 120, pl. 21, figs. 8–17. and pl. 22, 1885.

Numerous specimens taken from the stomach of a kahawai fish (*Arripis trutta* Forster) caught at Denham Bay, 8th September, 1908.

The species is very widely distributed, especially in southern seas.

Mr. Oliver states that during September and October the surface waters of the bay were literally full of shrimps and shoals of kahawai, and that heaps of shrimps were washed up on the beach. Humpback whales appeared in considerable numbers, and probably fed on these shrimps.

These "shrimps" may have been of various kinds, but the present species and the Hyperids mentioned below are the only pelagic forms in the collection that are likely to have occurred in great numbers.

Order AMPHIPODA.

Nannonyx kidderi (Smith).

Nannonyx kidderi Chilton, Subant. Islands N.Z., p. 615, 1909 (with synonymy).

One small egg-bearing female from Coral Bay, Sunday Island.

This specimen seems to be quite the same as specimens from New Zealand that I have referred to this species. The telson has the sides considerably upturned, and bears one long and one short plumose seta on each margin; the posterior margin has a rather deep though fairly wide indentation, each portion ending posteriorly in two or three stout setae. Third uropod of normal shape for the species; the inner ramus very small.

Eurythenes gryllus (Licht.).

Gammarus gryllus (H. Lichtenstein) in Mandt., Observ. Groenl., p. 34, 1822. *Euryporeia gryllus* Chevreux, Résultats Campagnes Sci. Albert 1er de Monaco, fasc. 16, p. 24, pl. 14, fig. 4. *Eurythenes gryllus* Stebbing, Das Tierreich Amphip., p. 73, 1906.

I have one imperfect specimen from Sunday Island which from its size and other characters certainly belongs to this species. The body is 35 mm. in length, and the shape of the different segments and of the side plates and the dorsal depression on pleon segments 3 and 4 agrees well with

that given for this species. The dorsal carina is well marked; it is pretty distinct on segments 4–7 of the peraeon and 1–4 of the pleon, and there is some indication even on the third segment of the peraeon. The specimen was evidently much decayed before it was collected, and nearly all the appendages are wanting; the greater part, however, of the second gnathopods is still present, and agrees well with the description given by other authors. The same is also true of the mouth parts, so far as I have been able to examine them.

The species is well known in northern seas, and has also been taken in various places in the Atlantic and near Cape Horn. Its occurrence at the Kermadecs is interesting, and shows that it probably distributed widely in southern seas.

It is celebrated as being one of the largest of the *Amphipoda*, the length sometimes being as much as 90 mm.

Moera mastersii (Haswell).

Moera mastersii Stebbing, Das Tierreich Amphip., p. 439, 1906 (with synonymy).

Two specimens from Coral Bay, Sunday Island.

In colour, shape of the body, eyes, and appendages these specimens agree closely with the description given by Stebbing.

The species is known from Torres Strait and Port Jackson.

Melita inaequistylis (Dana).

Melita inaequistylis Chilton, Subant. Islands N.Z., p. 630, 1909 (with synonymy).

One male specimen taken at low-water mark at Coral Bay, Sunday Island, by Mr. T. Iredale.

This specimen has the fourth pleon segment without teeth, the fifth with 2 or 3 small teeth, and the gnathopods show the characters usually present in adult specimens of this species from the main islands of New Zealand.

? Melita palmata (Montagu).

? *Melita palmata* Stebbing, Das Tierreich Amphip., p. 425, 1906 (with synonymy).

Two males and one female from Coral Bay, Sunday Island, appear to belong to this species.

It is only with much hesitation that I refer these specimens to this species, which, according to Stebbing, is known only from the North Atlantic and surrounding seas. In all three specimens the fourth pleon segment is produced dorsally to a compressed tooth, and segment 5 bears two small denticles, each with a bristle at the base, exactly as described by Stebbing for *M. palmata*, and the resemblance is very close in practically all the other characters, except that the lower antenna is nearly as long as the upper, and the secondary appendage of the latter consists of more than two joints—three in one specimen, and four in the others. The first gnathopod of the male is not specially modified, but has the propod and dactyl of normal shape, as in the female. The second gnathopod has the propod greatly enlarged and widened distally, but not produced into the rounded lobe shown in Sars's figure; the palm is moderately well defined, and is

rather convex, its margin being unevenly crenate; the dactyl is broad, subacute at extremity, and overlaps the propod.

There are some differences between my two male specimens, and it is evident from the account given by Stebbing that the gnathopods of this species have been differently described by different authors, the explanation probably being that these appendages vary considerably with age and sexual development.

The teeth on the pleon segments also show considerable variation in some of the species of *Melita*, so that the discrimination of the species is peculiarly difficult.

In the meantime I refer my specimens to *M. palmata*, the species to which they appear to agree most closely. They cannot be identified with the preceding species, *M. inaequistylis*, for they differ considerably in the teeth on the pleon segments and in the shape of the second gnathopod of the male; unless, indeed, we are here dealing with one cosmopolitan and variable species in which there are several forms of the male, as appears to be the case with the next species, *Aora typica* Kröyer.

Aora typica Kröyer.

Aora typica Chilton, Ann. Mag. Nat. Hist., ser. 5, 16, p. 370, 1885; and Subant. Islands N.Z., p. 645, 1909: Stebbing, Das Tierreich Amphip., p. 587, 1906.

One male from Coral Bay, Sunday Island, with first gnathopod of the type described as *A. gracilis* by Spence Bate, and mentioned as "form 2" in my first paper quoted above.

This particular form of the male is very widely distributed.

? Orchestia gammarellus (Pall.).

? Orchestia gammarellus Stebbing, Das Tierreich Amphip., p. 532, 1906 (with synonymy).

Numerous specimens "in sand under stones above tide-marks, Coral Bay, Sunday Island."

These specimens are all rather small and probably not fully mature, and none of the males show any enlargement of the merus and carpus of the fifth peraepods, but in all other respects they appear to agree closely with the description and figures of this species by Stebbing and Sars. They seem to be indistinguishable from New Zealand specimens that I have referred to this species.

Parorchestia tenuis (Dana).

Parorchestia tenuis Stebbing, Das Tierreich Amphip., p. 557, 1906 (with synonymy); Chilton, Subant. Islands N.Z., p. 642, 1909.

Four specimens from a fresh-water stream, Sunday Island.

These specimens are too close to New Zealand examples to be looked upon as a separate species. They differ, however, from Stebbing's description and from typical specimens in having the first gnathopod of the male slightly more slender and more spinous, and the outer rami of the first and second uropods provided with 2 or 3 small marginal spines.

In New Zealand the species is common in brackish water at the mouths of fresh-water streams, and occurs as far south as Campbell Island. An allied species, *P. hawaiensis*, is found in the Hawaiian Islands.

Parorchestia sylvicola (Dana).

Parorchestia sylvicola Stebbing, Das Tierreich Amphip., p. 558, 1906 (with synonymy).

Sunday Island: seven males and twelve females, "under dead nikau-leaves, Expedition Hill, 26th May, 1908"; and ten males and two females, "under dead fern-leaves, Moumoukai, 27th June, 1908."

I cannot find any point in which these specimens differ appreciably from typical New Zealand examples of this species. It will be noted that in the specimens submitted to me the males—*i.e.*, the specimens with large second gnathopods—are more numerous than the females, though on the mainland of New Zealand males are usually very scarce. Whether this depends on the method of collecting—*i.e.*, selecting the largest specimens—on the season of the year, or on the characteristics of a local variety I cannot say. I have elsewhere drawn attention to the similar abundance of males in the collection of different species of *Parorchestia* from the subantarctic islands of New Zealand (see Subant. Islands N.Z., p. 603).

Phrosina australis (Stebbing).

Phrosina australis Stebbing, Rep. Voy. "Challenger," 29, p. 1431, 1888.

One large specimen, Sunday Island (Captain Bollons, 1907); two smaller ones washed up on Flat Beach, Sunday Island (W. R. B. Oliver, 1908).

I refer these specimens to this species, of which a single specimen, under a quarter of an inch in length, was taken by the "Challenger" at Station 164D, east of Australia.

Mr. Stebbing says that the only difference of importance he can discover between *P. semilunata* Risso and this species is that the first and second uropods, "instead of having broadly rounded extremities, are distinctly narrowed and acute, or nearly so; the telson also is less rounded apically than in the other species." In my specimens the pleopods and telson are rather imperfect, but so far as they can be observed they do not seem to differ much from the figure of *P. semilunata* given by Stebbing. In the other points mentioned by Stebbing my specimens seem to agree with his, but the differences from *P. semilunata* appear to be very trivial, and but for the locality in which they were found I should be inclined to refer my specimens to that species.

Phronima novae-zealandiae Powell.

Phronima novae-zealandiae Powell, Trans. N.Z. Inst., 7, p. 294, 1875; Stebbing, Rep. Voy. "Challenger," 29, p. 1356, 1888.

Several specimens washed up on Low Flat Beach, Sunday Island.

Platyscelus intermedius G. M. Thomson.

Platyscelus intermedius G. M. Thomson, Trans. N.Z. Inst., 11, p. 244, pl. 10D, fig. 4, 1879.

Several specimens from Sunday Island (Captain Bollons); one from stomach of a kingfish, Sunday Island (W. R. B. Oliver).

Mr. Stebbing says that this species "seems scarcely, if at all, distinguishable from *Platyscelus ovoides*."

Oxycephalus clausi Bovallius.

Oxycephalus clausi Stebbing, Rep. Voy. "Challenger," 29, p. 1583, pl. 202, 1888.

One specimen cast up on Terrace's Beach, Sunday Island, and two imperfect specimens washed up on Flat Beach.

The perfect specimen agrees closely with Stebbing's descriptions and figure. He points out that the species is nearly allied to *O. edwardsii* G. M. Thomson, which is occasionally washed up on New Zealand shores, but that there are differences in the gnathopods, the fifth peraeopod, &c. In the Kermadec specimens "the postero-lateral angles of the first three segments [of the pleon are] produced into a short sharp point, behind which, at some distance, the hind margin forms a similar point" as described by Stebbing, while in *O. novae-zealandiae* it is only the hind margin that is produced into a point.

Caprella acutifrons Latreille.

Caprella acutifrons Mayer, Die Caprelliden der Siboga-Expedition, 24, p. 79, pl. 3, figs. 4–28; pl. 7, figs. 62–65; 1903.

A large number of specimens of both sexes and of various sizes "from husk of cocoanut washed up on Denham Bay Beach, Sunday Island."

These specimens show all the essential characters given by Mayer, and must be referred to this widely distributed species. The assignment of them to any one of the numerous varieties described by him is a much more difficult task; but in the shape of the second gnathopod, with its concave palm, &c., the thickened peduncle of the first antenna, and the lateral expansions of the third and fourth segments of the body they resemble var. *porcellio*, from the Cape of Good Hope.

Another variety occurs at Port Jackson, Australia, and the species as a whole is very widely distributed, though it has not been recorded from New Zealand.

Order ISOPODA.

Rocinela orientalis Schiödte and Meinert.

Rocinela orientalis Schiödte and Meinert, Naturhistorisk Tidsskrift, ser. 3, 12, p. 395, pl. 13, figs. 1–2, 1879; Stebbing, Trans. Linn. Soc., Zool., 14, p. 101, 1910; Richardson, U.S. Bureau of Fisheries, Document No. 736, 1910.

One ovigerous female cast up on Denham Bay Beach, Sunday Island.

This specimen agrees very closely indeed with Schiödte and Meinert's description and figures. The whole of the dorsal surface is light brown in colour.

They record the species from the Philippines and from Calcutta; the specimen examined by Mr. Stebbing was from Zanzibar.

Meinertia imbricata (Fabricius).

Oniscus imbricatus Fabricius, Mantissa Insectorum, 6, p. 241, 1787. *Ceratothoa banksii* Miers, Cat. N.Z. Crust., p. 105, 1876. *Meinertia imbricata* Stebbing, South African Crustacea, pt. 1, p. 58, 1900.

Several small specimens from Sunday Island (Captain Bollons, 1907); others from the throat of a "maomao" (*Scorpis aequipinnis*), Sunday Island (W. R. B. Oliver, 1908); and one collected by Mr. Roy Bell.

The species is widely distributed in the Indian Ocean, South Africa, &c.

Nerocila macleayii (Leach).

Nerocila imbricata Miers, Cat. N.Z. Crust., p. 107, 1876. *Nerocila macleayii* Chilton, Trans. N.Z. Inst., 23, p. 68, pl. 11, 1891.

Two specimens from Sunday Island, collected by Captain Bollons.

Dynamenella huttoni (G. M. Thomson).

Dynamene huttoni G. M. Thomson, Trans. N.Z. Inst., 11, p. 234, pl. 10A, fig. 6, 1876. *Dynamenella huttoni*, Chilton, Subant. Islands N.Z., p. 657, 1909.

One specimen collected at the islands by Captain Bollons.

The species is common on the New Zealand coasts, and has been recorded from the Antipodes Islands.

Cilicaea caniculata (G. M. Thomson).

Nesea caniculata G. M. Thomson, Trans. N.Z. Inst., 11, p. 234, pl. 10A, fig. 7, 1879. *Naesea caniculata* Miers, Collections H.M.S. "Alert," p. 309, 1884. *Cilicaea canaliculata* Hansen, Q.J.M.S., 49, p. 123, 1905.

One male and one female "on brain-coral, 2 fathoms, Meyer Island."

In the male the end of the abdominal process has been broken off, but I think there can be no doubt that the specimens belong to the same species as the New Zealand specimens known by this name.

An allied species, *C. latreillei*, with several varieties, is found in Australian seas, and appears to differ in the details of the abdominal process of the male and of the uropods in both sexes.

Idotea metallica Bosc.

Idotea metallica Bosc., Hist. Nat., Crust., 2, p. 179, pl. 15, fig. 6, 1802; Miers, Journ. Linn. Soc., 16, p. 35, 1881; Chilton, Trans. N.Z. Inst., 22, p. 193, 1890; Stebbing, Trans. Linn. Soc., Zool., 14, p. 108, 1910 (with further synonymy); Thielemann, Abhand. Math-phys. Kl. K. Bayer. Akad. d. Wissenschaften, 2, Suppl.-band, 3 Abhand., p. 63, 1910.

One specimen cast up on the beach, Sunday Island.

A pelagic species, almost cosmopolitan in distribution. It has been taken in New Zealand seas.

Ligia novae-zealandiae Dana.

Ligia novae-zealandiae Dana, U.S. Expl. Exped., 14, Crust., pt. 2, p. 739, pl. 49, fig. 2, 1853; Chilton, Trans. Linn. Soc., 8, p. 107, pl. 11, fig. 1, 1901.

Several specimens from Sunday Island.

I refer these to *L. novae-zealandiae* with some hesitation. They agree in most respects, but have the body narrower than is usually the case in that species, and the uropoda are somewhat longer and, especially in the peduncle, slightly more slender. These specimens agree closely with the description given by Miers of specimens from Port Molle which he describes under the name "*Ligia gaudichaudii* var. *australiensis* Dana." As Miers pointed out, *L. novae-zealandiae* (including *L. quadrata* G. M. Thomson) is very close to the species which he was then describing. I have numerous

specimens from Victoria and Hobart which I have considered to be *L. australiensis* Dana, and these, though very close to *L. novae-zealandiae*, differ in a few details in the appendages, especially in the male, and until a careful comparison can be made of specimens from different localities I prefer to keep the two species distinct, and in the meantime to look upon the Kermadec Islands specimens as a local variety of the New Zealand species.

Trichoniscus kermadecensis sp. nov. Fig. 3.

Body oblong-oval, greatest breadth about half the length, narrowing somewhat to each end, pleon not abruptly narrower than peraeon. Dorsal surface of head and peraeon scabrous with small spinose tubercles, mostly arranged in transverse lines, a few small ones on segments 3–5 of pleon, but remainder of pleon nearly smooth.

Head much broader than long, antero-lateral angles a little produced and rounded, frontal margin slightly convex, first segment of peraeon with antero-lateral angles reaching half-way along the lateral margins of the head, posterior margin straight, posterior angles rectangular and slightly rounded; posterior angles of the second segment similar, those of the third to the seventh segments progressively more produced and acute, those of the seventh reaching almost to the end of the epimera of the third segment of the pleon; third, fourth, and fifth segments of pleon with fairly well-developed and evident epimera, terminal segment triangular, posterior margin straight with angles slightly rounded and bearing 3 or 4 minute setules.

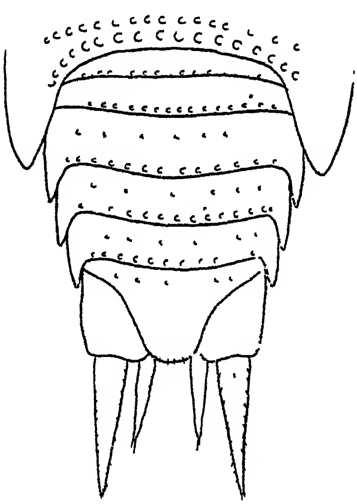

FIG. 3.—*Trichoniscus kermadecensis*: Pleon and uropoda.

Eyes of three ocelli slightly separated from one another.

Antennae rather stout, fourth joint of peduncle slightly tuberculated, fifth as long or longer and more slender, its anterior margin with 3 or 4 spiny tubercles, posterior margin with fine setae, flagellum slightly longer than the last joint of peduncle, indistinctly divided into 5 joints, with the usual pencil of long setae at the end. Uropods with basal joints very broad, extending a little beyond the posterior segment, outer ramus one and a half times as long as the base, inner ramus about half as long as the outer, its base concealed by the basal joint in dorsal view, both with a fur of fine setae and with a few long setae at the end.

Length of body, 4 mm.; breadth, 2 mm.

Colour.—Greater part of dorsal surface dark brown or almost black, with 2 broad indistinct bands of lighter markings a little to each side of the median line; some specimens much lighter in colour than others.

Hab.—Four specimens, labelled "Fresh-water stream, Sunday Island." It is probable, however, that these animals do not habitually live in the water, but in damp moss, &c., on the banks of the stream.

In the size, form of the body, character of the dorsal surface and of the appendages this species is close to *T. commensalis* Chilton, which is commonly found in ants' nests in New Zealand. That species differs, however, in colour and in the greater compactness of the body and in the shorter antennae and uropods, and it has the tubercles on the dorsal surface much better marked.

Philoscia oliveri sp. nov. Fig. 4.

Elongate-oval, widest at fourth and fifth peraeon segments, narrowing slightly anteriorly and posteriorly, dorsal surface with small sparsely scattered hairs. First two segments of peraeon with margin very slightly sinuous, first segment slightly longer than the others, postero-lateral angles of segments 5, 6, and 7 somewhat produced but not acutely, those of seventh segment reaching to the middle of the lateral margin of the second pleon segment. Pleon abruptly narrowed; first two segments a little shorter than the others; third, fourth, and fifth with very small adpressed epimera; last segment broader than long, sides slightly sinuous; extremity broadly rounded and bearing a few setules.

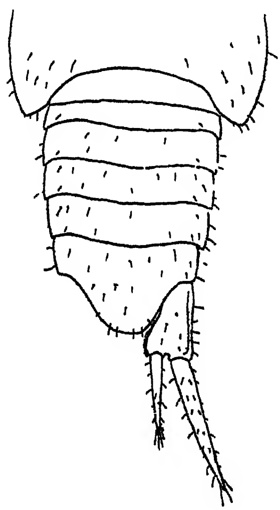

Fig. 4.—*Philoscia oliveri*: Pleon and uropod.

Antennae about half as long as the body, hirsute, second and third joints subequal, the fourth shorter than the fifth, and subequal with flagellum, the 3 joints of which are of about equal lengths. Uropods with the base extending beyond the telson, narrowed proximally, its outer side grooved and inner margin with a dense fringe of very short setae, inner ramus arising a little anterior to the outer and about half as long, both slender and hirsute; total length of uropod nearly equal to that of pleon.

Length, 5 mm.; greatest breadth, 2 mm.

Colour.—Light brown, with marblings of darker brown sometimes forming indistinct longitudinal bands, one central and two lateral. Mr. Oliver notes that the species is "very variable in colour."

Hab.—Expedition Hill and Mount Junction, Sunday Island; several specimens from each locality.

This species appears to belong to the same section of the genus as *P. pubescens* Dana from New Zealand, *P. mina* Budde-Lund and *P. hirsuta* Budde-Lund, both from the Cape of Good Hope. I have specimens, not yet described, from Norfolk Island which are a little broader and a little darker in colour, but which appear to be only a variety of the present species. *P. lifuensis* Stebbing, from the Loyalty Islands, presents some resemblances, but differs in the outline of the body and in the much shorter pleon and uropods.

I have named this to indicate my indebtedness to Mr. W. Reginald B. Oliver for the opportunity of examining the fine collection of *Crustacea* he made at the Kermadec Islands in 1908.

Metoponorthus pruinosus (Brandt).

Porcellio pruinosus Brandt, Conspectus Oniscidorum, pp. 181 (19), 188 (26), 1833. *Metoponorthus pruinosus* Budde-Lund, Crust. Isop. Terrest., p. 169, 1885: Chilton, Ann. Mag. Nat. Hist., ser. 7, 16, p. 428, 1905; and Trans. N.Z. Inst., 38, pp. 64, 65, 1906: Stebbing, Ann. South African Mus., 6, p. 440, 1910.

Numerous specimens found under logs, stones, &c., at Denham Bay, Sunday Island.

Mr. Oliver says of these specimens, "Perhaps introduced," and they certainly belong to this European species, which has now been distributed to most of the temperate regions. I have already discussed its occurrence in Norfolk Island and New Zealand in the papers quoted above.

Subclass CIRRIPEDIA.

Order THORACICA.

Lepas pectinata Spengler.

Lepas pectinata Darwin, Cirripedia (Lepadidae), p. 85, pl. 1, fig. 3, 1851; Hutton, Trans, N.Z. Inst., 11, p. 329, 1879; Gruvel, Cirrhipèdes, p. 107, fig. 119, 1905.

Numerous specimens from Sunday Island; some on *Spirula* shells. They agree well with Darwin's description.

The species is very widely distributed, and was recorded from Auckland, New Zealand, by Hutton in 1879.

Lepas denticulata Gruvel.

Lepas denticulata Gruvel, Cirrhipèdes, p. 107, fig. 118, 1905.

A few small specimens collected at Sunday Island by Captain Bollons in 1907 appear to belong to this species.

They agree well with the figure given by Gruvel, differing from *L. pectinata* in having the ridge on the scuta from the umbo to the apex situated some distance from the convex occludent margin; the carina is dorsally crested, and bears 4 or 5 well-marked teeth, but I cannot make out the projecting points on the two branches of the inferior fork, nor is the tooth on the internal umbonal angle of the left scutum distinguishable.

Gruvel's specimens are from the Philippines.

Lepas anatifera Linnaeus.

Lepas anatifera Darwin, Cirripedia (Lepadidae), p. 73, pl. 1, fig. 1, 1851; Gruvel, Cirrhipèdes, p. 103, fig. 121, 1905; Stebbing, Ann. South African Mus., 6, p. 563, 1910.

Numerous specimens which I refer to this species were obtained from Sunday Island.

These specimens can be separated pretty easily into three varieties. A few of them agree pretty closely with the type of this species as described by Darwin: in them the valves are almost smooth, the radiating lines not being prominent; the carina is rather narrow and fairly acuminate at the end. Many other specimens have the carina more or less distinctly barbed, and agree well with Darwin's "var. (*b*)"; in these the radiating

lines on the scuta are more distinct than in the specimens already referred to. A few specimens differ from both of the varieties already mentioned in having the carina much broader and less acuminate, not barbed, and in having little or no trace of an internal tooth on either scutum. The radiating lines on both scuta and terga are fairly distinct. These specimens therefore differ from the typical form of *L. anatifera* in the absence of the internal tooth on the right-hand scutum and in the shape of the carina. In some respects they seem to come pretty close to *L. testudinata* Aurivillius, from the Cape of Good Hope. They differ, however, from that species, as described and figured by Gruvel, in the broader carina and in the shape of its fork, and apparently also in having 5 teeth on the mandibles. Neither of these points is of much importance, and but for the absence of the internal tooth on the scutum there is perhaps little to distinguish *L. testudinata* from *L. anatifera*. In my Kermadec Island specimens both the scuta have the umbonal angle somewhat incurved, but there is nothing that can strictly be called a tooth on either of them. For the present I prefer to look upon these specimens as a variety of the wide-spread and variable *L. anatifera* It differs from *L. hillii* in having only two filaments. I have numerous specimens from the Chatham Islands that appear to be practically identical with this variety from the Kermadecs.

L. anatifera is almost cosmopolitan, but has not been recorded from New Zealand seas.

Lepas fascicularis Ellis and Solander.

Lepas fascicularis Darwin. Cirripedia (Lepadidae), p. 92, 1851; Gruvel, Cirrhipèdes. p. 105. fig. 116. 1905; Stebbing, Ann. South African Mus., 6, p. 564, 1910.

A single specimen washed up on Sunday Island.

This specimen has the short peduncle completely surrounded by a spherical mass formed of the secretion of the cement-glands, the whole forming a float, as described by Darwin.

Subclass OSTRACODA.

Order PODOCOPA.

Cypridopsis minna (King).

Cypris minna King, Proc. Roy. Soc. Van Diemen's Land, 3, p. 64, pl. 10B. *Cypridopsis minna* G. O. Sars, Fresh-water Entomostraca of N.Z., Vidensk. Selsk. Skr., 1, M.-N. Kl., No. 5, p. 30, pl. 4, figs. 3 *a-d*, 1894.

A few specimens from fresh-water swamps, Denham Bay, appear to belong to this species.

They agree well in shape of the valves with Sars's description and figures. The species is very near to *C. viridis* Thomson, and, like it, is found both in New Zealand and in Australia.

Ilyodromus smaragdinus G. O. Sars.

Ilyodromus smaragdinus G. O. Sars, Fresh-water Entomostraca of N.Z., Vidensk. Selsk. Skr., 1, M.-N. Kl., No. 5, p. 43. 1894.

Specimens from fresh water in swamps at Denham Bay and from under stones in shallow water, Green Lake, agree well with Sars's descriptions.

The type specimens were raised by Sars from dried mud from the neighbourhood of Dunedin, but the species doubtless occurs more widely in New Zealand.

I have several specimens of another Ostracod with the shell light-coloured, with 3 or 4 irregularly scattered patches of black or very dark-blue pigment on each valve. These I have not been able to identify.

Subclass BRANCHIOPODA.

Order CLADOCERA.

Daphnia thomsoni G. O. Sars.

Daphnia similis Thomson, Trans. N.Z. Inst., 16, p. 240, pl. 13, figs. 6–9, 1881. *Daphnia thomsoni* G. O. Sars, Fresh-water Entomostraca of N.Z., Vidensk. Selsk. Skr., 1, M.-N. Kl., No. 5, p. 5. 1894; Stebbing, Ann. South African Mus., 6, p. 489, 1910. *Daphnia similis* Claus var. *thomsoni* Richard, Ann. Sci. Nat., ser. 8, vol. 2, p. 217, pl. 25, figs. 13, 14, 1896.

Numerous specimens from fresh water in swamps at Denham Bay; collected on 20th June, 28th July, and 28th September, 1908.

I have been able to compare these specimens with some from the type locality, Eyreton, North Canterbury, New Zealand, and can detect no difference except that the Kermadec specimens have both the head and the body a little less broad. In them, too, the spine of the carapace is longer than in most of my New Zealand specimens, but the length of this varies, and, according to Sars's observations, is longest in specimens of the earliest generations, in these attaining nearly half the length of the carapace, as in the Kermadec specimens. It will be noticed that Mr. Oliver's collections were all made early in the season, the first on the 20th June.

The species is known both from New Zealand and from the Cape of Good Hope.

Dr. Jules Richard considers *D. similis* Thomson simply a variety of the widely distributed species of the same name earlier established by Claus.

Subclass COPEPODA.

Order EUCOPEPODA.

Numerous specimens of a *Cyclops* were obtained in the fresh waters of the swamp at Denham Bay, and also from among weeds in Green Lake, but I have not yet been able to identify them satisfactorily with any of the numerous species of this genus known from Australia and New Zealand.

A few specimens of a *Pontella* were washed up on Flat Beach, Sunday Island, on the 6th June, 1908. The species has not yet been determined.

In the collection are also two parasitic *Copepoda*, one apparently a *Lepeophtheirus*, taken on the hapuka; and the other, which appears to belong to *Pandarus*, on a shark. Neither species satisfactorily identified.

Art. L.—*Sponges collected at the Kermadec Islands by Mr. W. R. B. Oliver.*

By Professor H. B. Kirk, M.A.

[*Read before the Wellington Philosophical Society, 5th October, 1910.*]

Plate XXVII.

In May of this year I received from Mr. W. R. B. Oliver a small collection of sponges from the Kermadec Islands. Apparently about eleven or twelve species are represented in the collection. Nearly all of these, so far as I have at present been able to examine them, are species hitherto undescribed. This is surprising, in view of the fact that the "Challenger" collections contained some sponges from the Kermadec Islands, and Von Lendenfeld has described others. It is remarkable also that there is so much distinctness from the Australian sponges. It is, however, highly probable that most of these Kermadec Island sponges are found in New Zealand. I hope to deal with the remainder of this collection in a subsequent paper.

In the descriptions in this paper I have not generally given the diameter of fibres, but the scale of the drawing is shown in each case. All drawings of fibrous skeletons are from specimens treated with water and afterwards carefully dehydrated and brought into balsam. In the dried specimens as received the fibres were in nearly all cases much shrunken.

Genus Tethya Lamarck.

More or less spherical *Tethyidae,* without highly specialized pore-bearing grooves, and without a sand-layer in the choanosome.

Tethya lyncurium Lin. var. australis var. nov. Fig. 1.

Sponge about 2 cm. in diameter and 1·5 cm. in height. Surface marked by rounded elevations and depressions, the elevations echinated by the spicules of the brush. No appearance of tesselation. Colour of formalin-preserved specimen pale yellow.

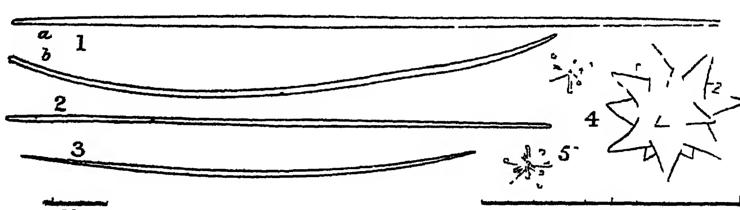

Fig. 1.—*Tethya lyncurium var. australis.*
1*a*, 1*b*. Styli. 2. Strongyle. 3. Oxeote. 4. Spheraster. 5. Chiaster.

The general arrangement of the skeleton is that of the typical *T. lyncurium.* Megascleres are for the most part styli (fig. 1, 1*a*, 1*b*) with the base rounded, the apex usually blunt but sometimes sharp, and the widest part of the spicule about a third of the distance from the base. The styli vary in size; an average size is 1·3 mm. by 0·02 mm. There are

a smaller number of strongyloxea, 1·05 mm. by 0·015 mm., and a few undoubted oxea, 0·9 mm. by 0·015 mm. Spicules of all three kinds occur also in the choanosome, between the rays. The microscleres are very small chiasters, and larger and more massive spherasters. The chiasters are most abundant just at the surface of the sponge, where they form a close layer, as in the type (see Bowerbank, "British *Spongiadae*," vol. 2, p. 93). They are also abundant in the inner portion of the ectosome, and are freely scattered throughout ectosome and choanosome. The spherasters are unevenly scattered through the ectosome, and are rare in the choanosome. The chiasters have a very small centrum, and about 12 slender straight rays always distinctly tylote. This tylote termination of the rays is like that of *T. japonica*, figured by Sollas (IX, pl. xliv), and that of *T. lyncurium* var. *a*, described by Dendy (IV, p. 113). The chiaster is noticeably different from that of the type as figured by Schmidt (VIII, pl. iv), Carter (XI, pl. ii), and others. Length of ray, 0·01 mm. The spheraster has a massive body and from 12 to 18 stout pointed rays, which are never spined. The length of the ray is 0·02 mm., and the total diameter of the spicule 0·06 mm.

This sponge is identical with one found on the New Zealand coasts, but not hitherto described. It is perhaps identical with Lendenfeld's *T. multistella* (V, p. 46), in which, however, no strongyloxea nor oxea are reported. It is also very near Dendy's *T. lyncurium* var. *a* (IV, p. 113). I note these points of difference :—

T. lycurium var. *a*.	*T. lycurium* var. *australis*.
Vent noticeable in preserved specimens.	Vent not noticeable in preserved specimens.
Megascleres : Styli faintly tylote. No oxea nor strongyla.	Styli not tylote. Oxea and strongyla present.
Microscleres : Spheraster rarely spined. Spheraster-rays about 12.	Spheraster never spined. Spheraster-rays usually more than 12.
Chiaster : Rays 6–9.	Rays more than 9.

I propose to establish this variety with some reluctance, and only do so to avoid any possible confusion in notions of distribution.

Five specimens were received, preserved in formalin. "Meyer Island, near Sunday Island, in rock-pools ; 24/4/08."

Genus RENIERA Nardo.

Skeleton forming a close reticulation of usually single megascleres, each forming one side of a mesh. Spicules short, usually oxeote. In most cases the ends of the spicules are bound to the adjacent spicules by a little spongin.

Reniera reversa n. sp. Fig. 2.

Sponge flattened and encrusting. Length, 4·5 cm. Thickness, 0·7 cm. There are a few scattered oscula flush with the surface of the sponge, and about 4 mm. in diameter.

The skeleton consists mainly of blunt oxea, which are slightly curved. These are bound together by scarcely discernible spongin into meshes which may be 3-, 4-, or 5-sided. From the upper surface of the sponge there project slightly curved styli, the blunt end directed outwards. These are imbedded for about half their length. They form various angles with the surface.

Size of spicules: Oxea 0·1 mm by 0·005 mm.; styl. 0·84 mm. by 0·014 mm.

Two specimens were received dry and somewhat broken. The label reads "Taken in rock-pools, Meyer Island (near Sunday Island); 29/2/08."

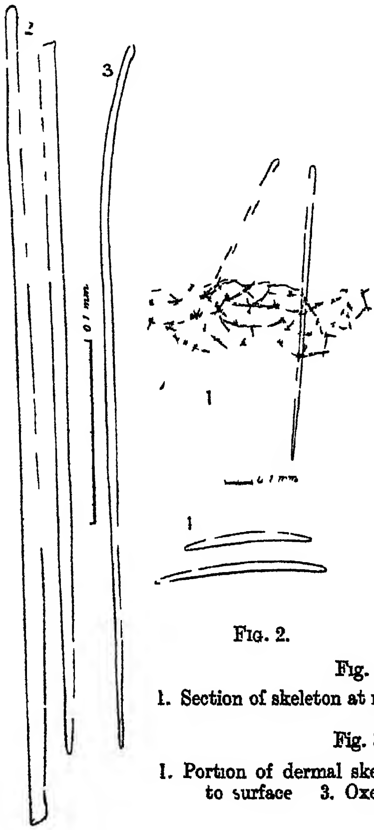

FIG. 2.

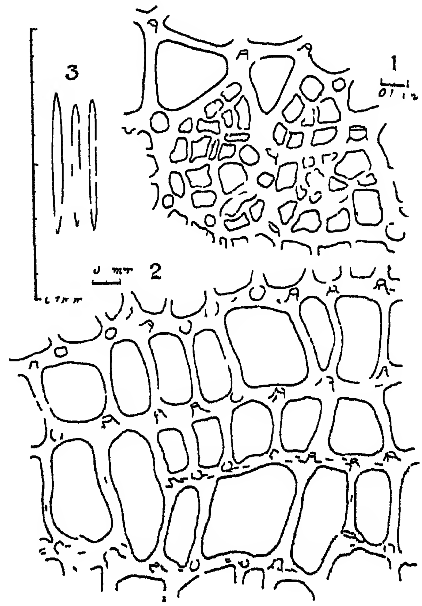

FIG. 3.

Fig. 2.—*Reniera reversa.*

1. Section of skeleton at right angles to surface. 2, 3. Styl. 4. Oxea

Fig. 3.—*Chalina fistulosa.*

1. Portion of dermal skeleton 2. Section of skeleton at right angles to surface 3. Oxea.

Genus CHALINA Grant.

Chalininae whose skeletal reticulation is typically rectangular. Fibres usually slender, with much spongin, and few, but usually well-developed, spicules.

Chalina fistulosa n. sp. Fig. 3.

Sponge massive, sessile; with well-developed oscula, oval or rounded, which terminate short fistular processes on the upper surface of the sponge. Fistulae from 5 mm. to 12 mm. in height; oscula from 5 mm. to 8 mm. in diameter. Surface smooth. Colour of dry specimen dirty-yellow. Texture harsh.

Internal skeleton showing approximately rectangular meshes. Longitudinal fibres usually a little stronger than the transverse ones, and loosely cored with a strand of spicules often arranged with some irregularity. In the transverse fibres the spicules are few, never forming a connected strand and never polyserial.

Dermal skeleton shows fibres that are about the same diameter as the primary fibres of the internal skeleton, but dark in colour. They form a

Fig. 2.—Toxochalina oliveri.

Fig. 1.—Clathriodendron rubrum.

polygonal network, the meshes of which are broken up by finer, irregular fibres of light colour. Spicules are never polyserial in the dermal skeleton, and are more numerous in the secondary fibres. Many lie outside the fibres.

Spicules are all oxea, straight or slightly curved, running somewhat suddenly to a fairly sharp point. Size, 0·05 mm. by 0·004 mm.

This sponge appears to be close to Dendy's *C. clathrata* (IV, p. 151) and to Topsent's *C. similis* (X, p. 481).

A single dry specimen received. "Cast up on Denham Bay beach, Sunday Island; 27/7/08."

Genus Toxochalina Ridley.

Ridley (VII, p. 402) founded the genus *Toxochalina* for "*Chalinidae* with well-developed horny fibre arranged rectangularly. Spicules, a skeleton acerate and a tricurvate acerate ('Bogen') flesh spicule."

One of the Kermadec Island sponges is a *Chalina* in every respect of structure, except that it has minute flesh spicules in the form of oxea. In view of the fact that many of the *Chalininae* have been described from beach-worn specimens, and some of them may yet be found to possess flesh spicules, it seems unwise to establish—at present, at all events—a new genus differing from *Toxochalina* only in the form of its microscleres. I therefore suggest a slight emendation of the generic character to admit sponges differing from *Chalina* in the presence of simple linear microscleres.

Toxochalina oliveri n. sp. Fig. 4, and Plate XXVII, fig. 2.

Sponge attached by the greater part of the lower surface. Oscula prominent, on the summit of rounded elevations on the upper surface, or on the crest of level ridges formed by the concrescence of such elevations. Colour yellowish-buff. Texture firm. Length of specimen, 9·5 cm.; width, 6 cm.; height, 1·5 cm.

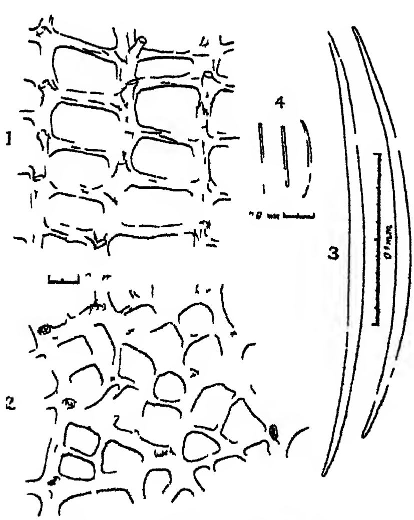

Fig. 4.—*Toxochalina oliveri.*
1. Section of skeleton at right angles to surface. 2. Portion of dermal skeleton. 3. Oxea. 4. Microscleres.

Structure of skeleton: Primary fibres running in parallel or in radiating lines to the surface, connected by the secondary fibres, which form with them and with each other rectangular meshes. The primary fibres contain an uneven strand of oxea loosely and irregularly arranged, most numerous at the nodes. The strand thins out in places to the point of disappearance, but usually it consists of about six series of spicules. Secondary fibres thinner than the primary, containing few spicules, and these not polyserial and not in contact end to end. The general appearance of a section of the skeleton is very like that of *Siphonochalina procumbens* as figured by Dendy (III, pl. 58, fig. 4). In the dermal skeleton the meshes are subdivided by finer fibres (fig. 4, 2).

Spicules: The spicules of the skeleton are slightly curved oxea with bluntish ends. Size, 0·24 mm. by 0·008 mm. The microscleres are minute strongyla, smooth and straight or slightly curved.

The sponge is quite unlike *Toxochalina foliodes* (*Desmacidon foliodes* Bowerbank), reported by Lendenfeld (VI, p. 797) from Thursday Island. That sponge is not in Mr. Oliver's collection.

A single dry specimen received. "Cast up in Coral Bay, Sunday Island; 2/5/08."

Genus Clathria Schmidt.

"*Ectyoninae* of various habit, frequently clathrous. Skeleton a reticulation of fibre, usually with much spongin, containing smooth styli and echinated by spined styli."—Dendy (IV, p. 170).

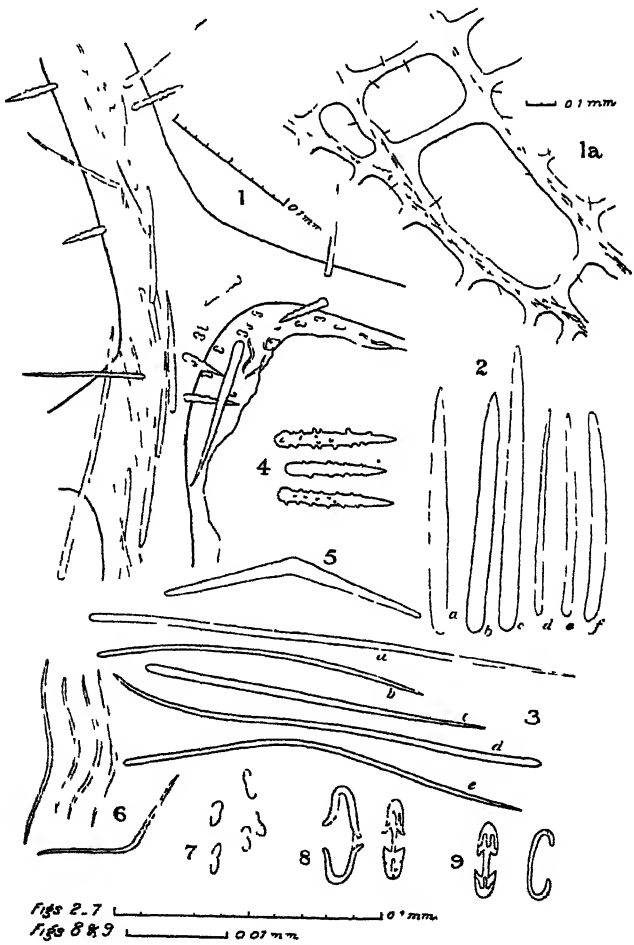

Fig. 5.—*Clathria intermedia.*

1. Portion of skeleton. 1*a*. Portion of skeleton at right angles to surface. 2 *a*, *b*, *c*. Echinating smooth styli. 2 *d*, *e*, *f*. Smooth styli, sometimes echinating, more often in fibre or in sponge-flesh. 3 *a*, *b*, *c*, *d*, *e*. Smooth slender styli of fibre and sponge-flesh. 4. Echinating spined styli. 5. A diact spicule in boiled-out preparation. 6. Toxa. 7, 8. Isochelae. 9. Simple sigma.

A Clathrioid sponge in Mr. Oliver's collection has both smooth and spined echinating styli. I think it best to interpret the generic character as to echination to mean that there must be spined echinating styli and that there may be smooth echinating styli as well, rather than to establish a new genus for this sponge.

Clathria intermedia n. sp. Fig. 5.

Sponge massive, encrusting, harsh to the touch. On the upper surface are numerous low, conical elevations, each terminating in a circular osculum, which is about 3 mm. in diameter.

The single specimen is 5 cm. long, 1·5 cm. high. Colour brownish-grey.

Skeleton showing primary and secondary fibres. The former generally radiate from the walls of the gastral cavity to the surface; the latter connect the primary fibres, giving approximately right-angled meshes. Colour in balsam light amber. The primary fibres are cored by a strand of smooth styli, the strand being from 1 to 4 spicules thick. The apex of the spicules is nearly always directed towards the surface of the sponge, where one or two of these smooth styli may project from the end of the primary fibres. Secondary fibres seldom contain spicules. Both primary and secondary fibres are echinated sparsely by smooth and by spined styli in about equal numbers. Only the base of the echinating spicule is imbedded in the spongin, and the spicules project at almost right angles to the fibre. There is no special dermal skeleton. The sponge-flesh contains abundant smooth styli showing no definite arrangement.

Spicules: Megascleres all styli. (1.) The most characteristic are fairly stout spicules with well-rounded base, the broadest part of the spicule being about one-third of the length from the base. These spicules usually run abruptly to a sharp point. Size, 0·1 mm. by 0·009 mm. The smooth echinating spicules are all of this kind, as are most of these that core the fibres or that lie loose in the sponge-flesh. In the latter position the styles may be blunt, and there are long and slender styli. The most slender have a thickness of about 0·001 mm., and these may be variously curved. (2.) Spined styles occurring as echinating spicules only; somewhat tylote, spines irregularly scattered, directed straight outwards. The spicule tapers to a fairly sharp point. The apical portion of the spicule—about one-sixth of the whole length—is the only part that is always free from spines. Microscleres—(1) Isochelae, palmate. As the spicule lies on its side it presents a distinct indentation on the convex side; this represents the shank of the spicule, along which the palmate expansion does not extend. (2.) Simple sigmata, somewhat larger than the isochelae. These are few in number. (3.) Toxa, slender, sharp-pointed; usually with a well-marked primary curve, and feeble secondary curves.

A single dry specimen. "Cast up on Denham Bay beach, Sunday Island; 27/7/08."

Genus CLATHRIODENDRON Lendenfeld (V, p. 215).

"*Desmacidionidae* with exceedingly large tylostylote megasclera. The spongin fibres of the supporting skeleton contain only few spicules. Echinating spicules spined styli."

Clathriodendron rubrum n. sp. Fig. 6, and Plate XXVII, fig. 1.

External Characters: Sponge erect, branching freely, the branches spreading widely. Branching begins close to the basal disc, and here the branches are thick and in section roundish or oval; above they become flattened and expanded, the ultimate branchings being digitate processes on the margins of these palmate portions. Surface unbroken by conuli; no oscula observable in the dry state. Height of largest specimen, 9·5 cm. Colour of dried specimen reddish-brown, becoming dark red on immersion

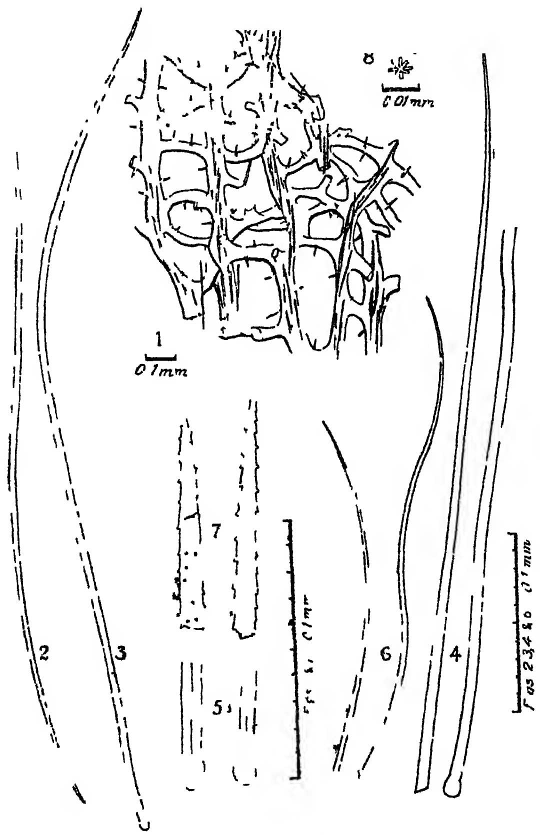

Fig. 6.—*Clathriodendron rubrum*.

1. Section at right angles to surface. 2. Oxeote. 3. Stylus. 4. Tylostyli. 5. Bases of tylostyli. 6. Filiform tylostyli. 7. Spined styli. 8. Doubtful microscleres.

in water. The colouring-matter is in the sponge-flesh, and dissolves out readily; it appears to be due to associated *Algae*. Skeleton tough, and harsh to the touch, becoming soft when wetted.

Skeleton reticulated; spongin abundant; primary fibres generally radiating, and somewhat uneven. The secondary fibres form with them meshes that are oval or polygonal, or often rectangular, the rectangular shape most observable in the younger parts of the sponge. Primary fibres cored more or less abundantly with smooth slender styli and tylostyli,

among which are a few slender oxea. Similar spicules lie in the sponge-flesh, and often parallel to the fibres. Secondary fibres not cored. Both primary and secondary fibres are sparsely echinated by spined styli. On the older surfaces of the sponge the echinating spicules are much more numerous, and many of the styli that lie outside the fibres become closely bound to them.

Spicules: Megascleres—(1.) Smooth styli. These are long and slender, and variously curved. They may be 0·5 mm. long, but seldom exceed 0·005 mm. in thickness. The thickest part of the spicule is usually about one-quarter of the length from the base. Apex sharp. (2.) Smooth tylostyli; very numerous, and presenting much variation. The most characteristic are, on an average, 0·7 mm. long and 0·008 mm. thick; apex sharp, base either simply tylote or with the tylosis not quite terminal (fig. 6, 5). There are also exceedingly slender, hairlike tylostyli, sometimes with a double tylosis (fig. 6, 6). (3.) Oxea: These are not numerous; they are slender and variously curved. Length, 0·045 mm.; usually sharp-pointed. Intermediate forms between these and the smooth styli occur. (4.) Spined styli: These occur as echinating spicules only. They usually taper from near the base to the apex. Size, 0·09 mm. by 0·007 mm. Spined irregularly throughout their length, the spines directed backwards. Microscleres (?): There occur both in the sections and in the boiled-out preparations, numerous irregular rodlike bodies that are possibly microscleres (fig. 6, 8). They are usually straight, and may be scattered or arranged in starlike masses. They seldom exceed 0·005 mm. in length.

Three specimens received, two of them small and battered. Owing to the great length of the characteristic spicules and to the fact that the sponges had been much crushed in transit, the longer spicules are usually broken.

"Cast up on Denham Bay beach, Sunday Island; 29/8/08."

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Art. LI.—*Anatomy of* Siphonaria obliquata (*Sowerby*).

By A. J. Cottrell, M.A., M.Sc. (N.Z.).*

Communicated by Professor Benham.

[*Read before the Otago Institute, 1st November, 1910.*]

Plates XXVIII, XXIX.

Habits, etc.

Siphonaria obliquata is a marine Gastropod, being one of the commonest characteristic of our shores. Superficially it resembles the limpet, and, like the latter, it is found in rocky places attached to rocks which are covered at high tide. I have collected specimens of this mollusc on the rocky beaches at Portobello (Otago Harbour), St. Clair, Brighton (Dunedin), and Oamaru. I have also examined specimens collected at Kaikoura, and also some very fine specimens from Wellington. When out collecting I have found them always in the same regions as limpets, but on the parts of the coast I have visited they are not nearly so plentiful as the latter. As a rule, the large specimens were found in out-of-the-way crevices in the rocks, well above the low-water mark. Others, however, were found nearer the low-tide mark, while many of the smaller specimens were collected from pools.

Externals.

The Shell. Plate XXVIII, figs. 1, 4, 5; Plate XXIX, fig. 1.

The mollusc is protected by a strong calcareous conical shell, which can easily be distinguished from that of the limpet by the following features:—

In *Siphonaria* the apex of the shell lies nearer to the posterior end and to the left side of the middle line, while in *Patella* (all species found on our coast) the apex lies nearer the anterior end of the shell, and in the middle line (Plate XXVIII, figs. 1, 4, 5; *a*).

Ridges radiate from the apex to the margin, which is notched, and concentrically are the lines of growth. On the right side, starting from the apex and extending to the edge of the shell, is a triangular ridge which corresponds on the inner side of the shell to the siphonal groove or notch (Plate XXVIII, figs. 1, 5; Plate XXIX, fig. 1; *sn*). The external surface of the shell is dark in colour, resembling the rocks to which the creature adheres, while the inner surface is of a light colour, varying from a light cream to a brownish-yellow. The interior of the shell is coated with the usual nacreous layer, in which the muscle-impressions can be seen (Plate XXIX, fig. 1; *mt*). These indicate the points of attachment of the pallial muscles, both past and present. They form an almost complete ring, broken only in the region of the siphonal notch.

Body-wall. Plate XXVIII, figs. 1, 4.

The creature is divisible into head and body, but there is no neck. During locomotion these parts are distended, and protrude considerably beyond the shell (Plate XXVIII, figs. 1, 4), but when the tide is out the body is drawn into the shell, which comes into close contact round its margin

* This article is part of the thesis upon which the University of New Zealand awarded the author first-class honours in 1906.

with the rock, though not so closely as does that of the limpet. This is the condition in which I have most frequently found them. The thick body-wall surrounding the internal organs on the sides (Plate XXVIII, fig. 1; *bw*) is composed of a dense mass of muscular tissue, the fibres of which run in all directions, thus rendering a great variety of movement possible.

In all regions of the body-wall forming the sides of the mollusc some of the cells of the epidermis are differentiated to form multicellular mucous glands, which project inwards among the muscles. The cavity of each is club-shaped, the narrow part ending externally in a pore. Around this cavity the cells are arranged—large glandular vacuolated cells, the outlines of which are not distinct. These cells secrete the mucus or material which forms it. It is stored in the cells in the form of granules, which stain very deeply in borax carmine. These can be seen even under the low power as conspicuous red masses. The secretion is discharged into the cavity, and on the contraction of the muscles in the vicinity it reaches the exterior. These glands are very numerous, and some of them are of considerable size. When the animal is disturbed it shrinks up, causing a considerable quantity of mucus to be exuded.

Foot. Plate XXVIII, figs. 2, 3.

The foot is of considerable size, consisting of the whole of the ventral surface behind the head. In the case of specimens preserved in formol the foot is much shrunken (Plate XXVIII, fig. 2; *f*); but I managed to kill a fine specimen in a very well-distended condition, and then hardened it in a strong spirit. This specimen shows very well the extent of the foot (Plate XXVIII, fig. 3; *f*) There is a slight propodium, on to which a large pedal gland opens in the median line. This gland extends through the whole length of the foot (Plate XXVIII, fig. 3; *pg, p*). The foot, like the body-wall, is very muscular, and has the same structure as the latter, except that here are no mucous glands, and in this region the epidermis is composed of columnar cells. The beautiful movement of the muscular foot may be well seen if a living specimen be made to creep up the inside of a glass vessel. The action is similar to that of a snail.

Head. Plate XXVIII, figs. 1, 2, 3.

The head is marked off from the body by a slight furrow running transversely across the ventral side immediately in front of the foot, and extending upwards for only a short distance on each side (Plate XXVIII, figs. 1 and 2). Anteriorly the head is convex, and the thick wall investing it is continuous with the body-wall described above, and has the same structure. Ventrally the head is flat, and is in contact with the surface to which the mollusc attaches itself. Like the foot, this part of the head is used for effecting locomotion, and has the same histological structure. When distended the right and left lobes of the head can be well seen (Plate XXVIII, fig. 3; *rl, ll*). No tentacles are present on the head, though part of these lobes on either side may correspond to tentacles.

External Orifices. Plate XXVIII, figs. 1, 2, 3; Plate XXIX, figs. 2, 3.

The mouth is situated in the middle of the ventral side of the head; it is a transverse slit, somewhat crescentic in outline, and median in position (Plate XXVIII, fig. 3; *m*).

On the right side of the body is the respiratory orifice, situated half-way along that side (Plate XXVIII, fig. 1; *r*). In large specimens it is about

¼ in. in diameter. The orifice is bounded above by the mantle-edge, and below by the body-wall, which is here differentiated to form a kind of muscular valve (Plate XXVIII, figs. 1, 2; *ms*). To close the aperture this is brought into contact with the mantle-edge by means of its muscles. The creature thus has the power of opening and closing this respiratory orifice. The anus opens into this orifice on the lower side (Plate XXIX, figs. 2, 3).

The single genital pore also opens on the right side, at the junction of head and body (Plate XXVIII, figs. 2, 3; *gp*).

Mantle-edge. Plate XXVIII, fig. 2.

The free edge of the mantle extends all round the upper edge of the creature, just inside the shell (Plate XXVIII, fig. 2; *me*). This is the lower margin of the mantle, and normally it lies close to the shell all round and nearly flush with its margin. Its edge resembles in colour and form that of the shell. On irritation the pallial muscles draw it up into the shell with the body. In it are numerous blood-vessels, and it is probably respiratory. Mucous glands like those of the body-wall are present in this part of the mantle.

Morphology and Histology.

Pallial Organs. Plate XXVIII, fig. 7; Plate XXIX, fig. 2.

The shell is attached to the creature by means of the pallial muscles, which extend round the latero-dorsal margin of the body, except at the siphonal notch, thus forming a ring broken only at this point, as is indicated by the muscle-impressions on the shell mentioned above (Plate XXVIII, fig. 7; *pm*). At the siphonal notch and over the rest of the dorsal surface the tissues are quite free from the shell. The pallial muscles are thickest near the siphonal notch.

On dissecting the muscles away from the shell, the latter may be removed, and the mantle, which extends over the whole dorsal surface, is exposed (Plate XXVIII, fig. 7). It encloses between itself and the dorsal body-wall a large pallial chamber, which extends out as far as the pallial muscles, by which the mantle is attached to the body. In the region of the heart, however, the roof of the pallial cavity is attached to the dorsal wall of the pericardium. This chamber communicates with the exterior by the respiratory orifice opening on the right side—a comparatively small branchial aperture—a contrast to the extensive apertures of a large section of the Gastropods: in this feature *Siphonaria* resembles the Pulmonates. The pallial organs can be seen by transparency. Perhaps the most interesting of these organs is the lung; it is formed by about the anterior third of the mantle, which is very vascular (Plate XXVIII, fig. 7; *l*). Just behind this, on the left side of the chamber, can be seen the heart, lying in the pericardium; this I shall include in the account of the vascular system. The kidney is attached to the walls of the second third of the chamber, and immediately behind this the gill is seen forming a semicircular band round the posterior region (Plate XXVIII, fig. 7; Plate XXIX, fig. 2; *g*).

The lung is similar to that of the Pulmonates. From a vessel running round the anterior margin of the mantle numerous vessels are given off which run backwards in the mantle; some of these give rise to two and even three rami. A corresponding set of vessels take their origin among the terminations of these, and convey the blood to the pulmonary vein, which runs along the posterior edge of the lung to the heart (Plate XXVIII, fig. 7, *ef.v*, *af.v*; Plate XXIX, fig. 2).

The kidney is of a pale-brownish colour; it consists of two regions, dorsal and ventral, folded one over the other (Plate XXIX, fig. 2; *dk, vk*). The former is attached to the mantle, and near the respiratory orifice, close to the gill, has a small spherical swelling—the renal papilla—on which the renal pore opens (Plate XXIX, fig. 2; *rp*). The papilla is always more or less concealed by the gill. The ventral region is somewhat leaf-shaped in outline, and is attached in the same way to the floor of the pallial chamber. The whole of the kidney is glandular, and contains no extensive cavity as is seen in the kidney of, *e.g.*, *Anodonta* or *Unio*. On the left side the kidney lies close to the pericardium, the right end of which it partially surrounds.

The gill is composed of a series of laminae separate from one another, and each independently connected to the mantle by one of its lateral edges, the other edge hanging freely into the pallial chamber (Plate XXIX, fig. 2; *g*). As noticed above, this series of gill-laminae forms a semicircle round the posterior end of the pallial chamber. Running round the gill on its posterior side is a large vein—the afferent branchial vein; and there is another having a corresponding position on the anterior side—the efferent branchial vein. With these vessels the ends of each lamina are connected, the posterior end with the former vessel, and the anterior with the latter. Each lamina tapers at each end to a small tubular structure carrying a branch from one of these vessels on to the lamina. Between these two extremes each lamina spreads out and is thrown into longitudinal folds, and on the edges or ridges formed by these folds secondary laminae often arise. Dorsally some of these folds may unite with the mantle, especially in the case of those laminae forming that part of the gill near the respiratory orifice, where the gill is most strongly developed and the folding is very complicated.

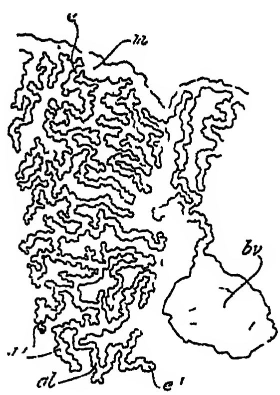

FIG. 1.—TRANSVERSE SECTION OF GILL-LAMINA; × 50.

bv, Anterior renal vein going to the kidney; *e*, edge of lamina attached to mantle; *e'*, free edge of lamina; *gl*, gill-lamina; *gl'*, secondary gill-lamina; *m*, mantle forming roof of pallial chamber.

Each surface of a gill-lamina is covered by a layer of ciliated epithelium, consisting of a single layer of cells, which are somewhat cubical, and contain large nearly circular nuclei. These nuclei stain very deeply in borax carmine. Between these two surfaces lies connective tissue containing blood-spaces. There are no skeletal elements in connection with this gill.

The blood flows from the posterior vessel into the gill-laminae, and, passing through the blood-spaces in them, is brought close to the water in the pallial chamber, and is thus aerated.

The gill is ciliated, and the water surrounding it is kept in motion by this means. The blood passes on, and is gradually collected into larger spaces, and finally, reaching the efferent vessel, is carried to the heart.

This gill seems to be quite different from the typical ctenidium; it does, however, resemble certain parts of the ctenidia of some opisthobranchs.

Alimentary System. Plate XXVIII, fig. 6; Plate XXIX, fig. 3.

The mouth perforates the thick muscular wall of the ventral side of the head in a direction vertically upwards, and leads into the cavity of the buccal mass—the "buccal cavity." The buccal mass is situated in the head, the cavity of which it practically fills. It is spherical in shape, of a dark colour, and is very muscular. Lying on the dorsal surface of the buccal mass, and usually almost concealing it, is a pair of salivary glands, one on each side. The oesophagus passes away from the buccal mass on the dorsal surface, arising near the anterior end, and, following the curve of the buccal mass, it passes backwards and downwards till it reaches the floor of the body-cavity, where it soon enters the stomach, which it joins on the ventral region of the anterior surface, the transition from oesophagus to stomach being very marked (Plate XXIX, fig. 3; *oc*, *st*). The stomach extends from the buccal mass to the posterior end of the creature, occupying a large part of the left half of the body-cavity. When distended it is cylindrical, and is of smaller diameter in the middle than at the two ends (Plate XXVIII, fig. 6; *st*). The digestive gland is very extensive; it occupies a large part of the posterior half of the body-cavity, and its lobes completely surround the posterior half of the stomach. It is really divisible into a right and a left part; the left is the larger, and the digestive juice is collected from its various lobes by ductules into the main ducts, which enter the stomach close together on the left side near the posterior end. The right part is much smaller; its duct joins the stomach on the right side, also near the posterior end (Plate XXVIII, fig. 6; *dg*, *dg'*).

The intestine passes away from the left side of the stomach, at the hinder end, posterior to and below the ducts of the digestive gland (Plate XXVIII, fig. 6; *i*). It is at first wide, but soon becomes a narrow thick-walled tube. After passing forwards and upwards it coils twice among the lobes of the digestive gland, and comes on to the dorsal surface on the right side, near the posterior end of the creature. It then runs forwards as the thin wall rectum, which on reaching about the middle of the length of the animal takes a sharp turn to the right, ending at the anus on the lower side of the respiratory orifice. Just inside the mouth, at the entrance to the cavity of the buccal mass, there is a chitinous jaw. This jaw is crescentic in outline, and extends from side to side of the buccal cavity on the anterior side of the mouth. When the creature is fully distended the jaw comes to the surface, and assists in breaking up food. It is attached at the lower end of the thick muscular anterior wall of the buccal mass to the chitinous lining of this region. The structure of this jaw is very similar to that of a radula; it is composed of a basement membrane of chitinous material, beset with numerous smal teeth. These teeth are cylindrical, pointed, all alike, and very numerous.

Captain Hutton seems to have incorrectly described this jaw as "Anterior margin papillate—rest smooth."*

The epithelium lining the buccal cavity is everywhere covered by a layer of chitin, which varies in thickness.

This cavity is blocked up by two similar and symmetrical muscular masses, one on each side of the middle line. Each is simply a muscular thickening of the wall of its respective side. Also projecting into the buccal cavity, behind these structures just described, is the "odontophore," with the radula. The radular teeth are comparatively small, very numerous, as in *Helix*, and are carried on a chitinous basal membrane. They are

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* Trans. N.Z. Inst., vol. 15, p. 141.

arranged in transverse rows, the average number of teeth in each row being about 120. Each row contains three kinds of teeth, and these are found in definite positions on the radula:—

1. A median tooth. This tooth is about half the size of those immediately to the right or left; it is conical and symmetrical (fig. 2; *mt*).

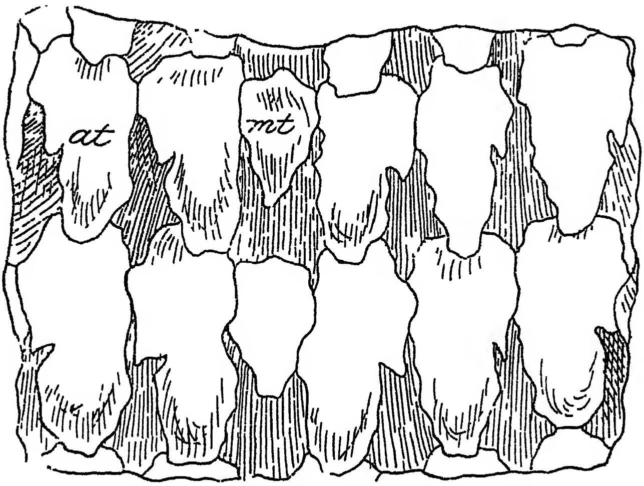

FIG. 2.—RADULA (× 370), SHOWING MEDIAN AND ADMEDIAN TEETH.
at, Admedian tooth; *mt*, median tooth.

2. To the right and left are a large number of admedian teeth, each of which is roughly conical, and on its outer side has a notch which gives rise to a second cusp about the middle of the outer side of the tooth (fig. 2; *at*).

3. The lateral teeth resemble the admedian, but each has three cusps; the median one is large, and, instead of being pointed, is broad and rounded: the lateral cusps, one on each side, are small, pointed, and occupy a corresponding position to those of the admedian teeth (fig. 3). Each radular tooth has a basal portion which is imbedded in the chitinous membrane supporting the teeth.

There is no sharp line of demarcation between admedian and lateral teeth, but one series graduates into the other.

FIG. 3.

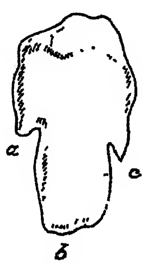

FIG. 4.

RADULAR TEETH; × 370.

Fig. 3. Side view of admedian tooth, showing base (*b*) and point (*p*).

Fig. 4. Lateral tooth, showing the three cusps (*a*, *b*, *c*).

The salivary glands are lobulate structures composed of large gland-cells with large round nuclei, which stain very deeply in borax carmine. Each gland tapers posteriorly, and the two are connected by a string of little lobes passing from the posterior end of one to the posterior end of the other.

This string is simply a continuation of the glandular tissue; it passes over the oesophagus, under the cerebral commissure—*i.e.*, it passes through the nerve-collar. The secretion of each gland is collected by ducts which ramify through the gland into a main duct. Each of these ducts (right and left) leaves its respective gland near the buccal ganglion, and, passing into the buccal mass close to the cerebro-buccal connective, discharges into the buccal cavity near the exit of the oesophagus. The stomach is quite different from the corresponding region in *Helix*: there is no crop as in *Helix*, and whereas the stomach of *Helix* is very small, that of *Siphonaria* is very large. But it may be urged that the anterior part of this region which I have called stomach may correspond to the crop of *Helix*, especially as the diameter of the tube is slightly less in the middle than at the ends. The posterior end of the stomach, as I have used the term, would then correspond to that of *Helix*. Yet for the following reasons I prefer to call it all the stomach: (1) The transition externally from oesophagus to stomach is very marked (Plate XXVIII, fig. 6; *st*), while it is not well marked in *Helix*; (2) the digestive fluid is discharged into the posterior end of one large chamber and is mixed with the food in that chamber, and this does not take place in *Helix*, but the food passes out of the crop to the small stomach further on, into which the digestive glands open.

Nervous System. Fig. 5, and Plate XXVIII, fig. 6.

The nervous system is characterized by the great concentration of its ganglia in the anterior part of the body. It consists of a ring of nerve-tissue surrounding the oesophagus immediately behind the buccal mass at the point where the oesophagus reaches the floor of the body-cavity (fig. 5; Plate XXVIII, fig. 6, *n*). The ganglia are confined to the lateral and ventral portions of the ring. In life they are of an orange colour, and can thus be readily recognized.

There is a pair of cerebral ganglia situated one on each side of the latero-dorsal surface of the oesophagus, lying almost on the sides. These are put into connection by a stout commissure which passes over the oesophagus (fig. 5; *cc*). Each cerebral ganglion gives rise to six or seven nerves, which innervate the cephalic region. Two of these nerves on each side go to the region round the mouth, and the others are distributed to the muscles and sense-organs of the floor and walls of this region, including the eyes.

From each of these ganglia a connective goes through the muscles of the buccal mass to the buccal ganglia. The buccal ganglia lie close together on the dorsal surface of the buccal mass under the oesophagus, at a point immediately behind where the latter becomes free of the buccal mass (fig. 5; *b*). These ganglia are ovoid in shape, and are connected by a well-defined commissure. They give off nerves supplying the muscles of the buccal mass.

The pleural ganglia (fig. 5; *pl*) lie very close to the cerebral, and practically abut upon them, so that the cerebro-pleural commissure is quite short. The left pleural ganglion gives rise to a connective passing straight across to the visceral ganglion, which lies very near to the right pleural ganglion, being separated from the latter by a very small ganglion, probably the representative of the parietal. Thus the right viscero-pleural connective is very short, and consequently the whole visceral loop is likewise very short, and the number of ganglia on it is reduced (fig. 5; *pv*, *pa*, *v*). Each pleural ganglion also gives off several nerves. From the left a large nerve

runs obliquely across the floor of the body-cavity, and is distributed to the walls and the mantle. There is a corresponding nerve from the right pleural, but it does not run so far back, going on to the body-wall just behind the penis. The pleural ganglion on this side also gives a stout nerve to the penis.

The visceral ganglion gives off a nerve passing back to the stomach (fig. 5; *g*), and another obliquely to the right; the branches of this latter nerve go to the body-wall and rest of the viscera. Close to the pleural

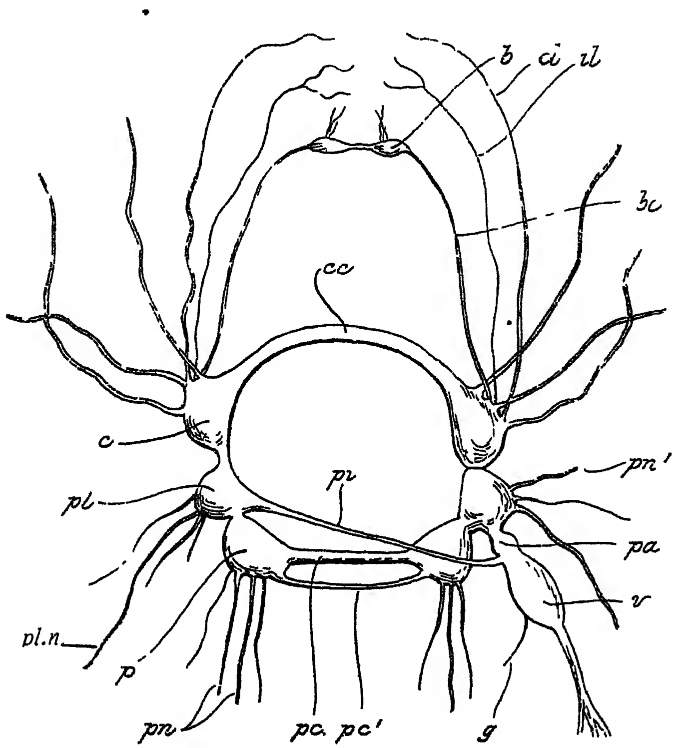

Fig. 5.—NERVOUS SYSTEM.

b, Buccal ganglion; *bc*, cerebro-buccal connective; *c*, cerebral ganglion; *cc*, cerebral commissure; *el*, external labial nerve; *g*, gastric nerve; *il*, internal labial nerve; *pa*, parietal ganglion; *pc*, pedal commissure; *pc'*, para-pedal commissure; *pl*, pleural ganglion; *pl.n*, pleural nerve; *pn*, pedal nerves; *pn'*, penial nerve; *p*, pedal ganglion; *pv*, pleuro-visceral connective; *v*, visceral ganglion.

ganglia on the underside of the oesophagus lie the pedal ganglia, one on each side. These are connected by a stout commissure which is much shorter than the cerebral commissure. It is supplemented by a second (para-pedal) commissure of about half its own thickness (fig. 5; *p*, *pc*, *pc'*). The pedal ganglia are, of course, connected to the cerebral by connectives. These lie anteriorly, and so close to the other ganglia that they are not easily seen. The pedal ganglia give rise to several stout nerves, which innervate the muscles of the foot.

Sense-organs. Plate XXVIII, fig. 4.

Distributed all over the external surface of the body are tactile organs, as evidenced by the fact that when a part of the epidermis is stimulated the creature withdraws that region, and so adjusts itself to its environment.

I looked for an otocyst, but was unable to find one.

A pair of eyes is present. Each is situated on the anterior region of the head, well to the side, and symmetrically placed with regard to the other (Plate XXVIII, 4; *e*). I discovered them by cutting a series of sections through the head of a young specimen. Each appears to lie imbedded in the muscles of the cephalic wall, at the base of a little depression which deepens when the animal shrinks up, and the eye is concealed. Usually the eyes cannot be distinguished in an external examination, but two specimens I managed to get so well distended that the eyes were clearly visible. Captain Hutton, in his brief account of the New Zealand *Siphonaridae*, says no eyes are present.*

The eye is of the usual molluscan type—densely pigmented, and containing the usual homogenous lens filling its cavity.

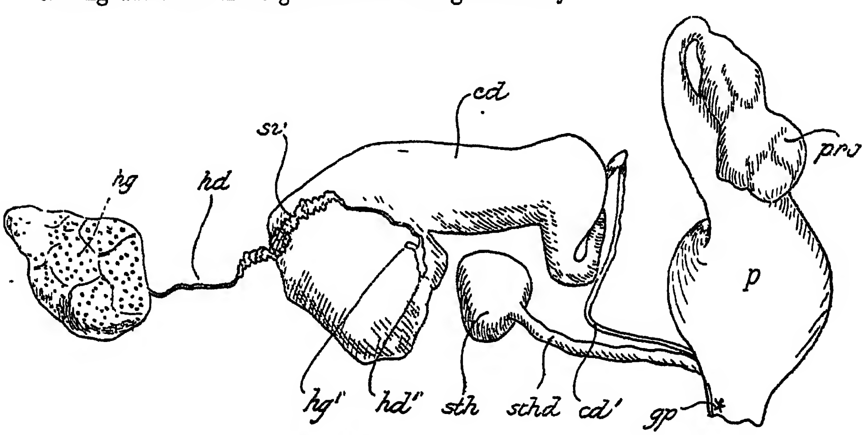

Fig. 6.—Reproductory System; × 2.

cd, Common duct—glandular region; *cd'*, common duct—non-glandular region; *hd*, hermaphrodite duct; *hd'*, small process formed of coil of hermaphrodite duct; *hg*, hermaphrodite gland; *hg'*, point at which hermaphrodite duct enters the common duct; *p*, penis; *pro*, prostate; *sthd*, spermotheca duct; *sth*, spermotheca; *sv*, seminal vesicle; *gp*, genital pore.

Reproductive System. Figs. 6, 7, and Plate XXIX, fig. 3.

Siphonaria obliquata is hermaphrodite; the organs of reproduction are both large and complicated, and comprise a hermaphrodite gland, a large glandular common duct, spermotheca, and a large penis (fig. 6; *hg*, *cd*, *sth*, *p*). These occupy a large part of the right half of the body-cavity. The genital products arise in the hermaphrodite gland, a dull orange-coloured organ lying partially imbedded in the digestive gland on the right side, near the posterior end of the body. It consists of several lobes, and on gently separating these there can be seen issuing from them little white ducts, which unite to form a main duct—the hermaphrodite duct. This

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* Trans. N.Z. Inst., vol. 15, p. 140.

duct is of small diameter; it passes forward, and after reaching the posterior extremity of the common duct runs across its large posterior region (fig. 6; *hd*). After a sharp bend, which gives rise to a small finger-shaped process (*hd'*), it enters the posterior end of the common duct, which end is directed forwards owing to the fact that this extreme posterior part of the common duct is bent upon itself. About the middle of its length the hermaphrodite duct dilates somewhat, giving rise to the seminal vesicle, which rests on the posterior end of the common duct (fig. 6; *sv*). The common duct consists of two parts—glandular and non-glandular. (1.) For about half its length the duct is large and very glandular; this region runs forwards, and, except for the posterior bend mentioned above. is quite straight (fig. 6; *cd*). (2.) The duct then gradually loses its glandular character, and tapers to a tube of comparatively very small diameter; at the same time it bends sharply on itself twice, and then on reaching the body-wall it bends forward again, running on the left side of the spermotheca duct towards the penis (fig. 6; *cd'*). At the side of the glandular region of the common duct is the spermotheca, a spherical greyish sac supplied with a stout muscular duct which runs forwards with the common duct, both entering the penis close together near the genital pore (fig. 6; *sth. sthd, cd', gp*).

The penis is a large muscular pyriform organ, occupying the anterior region of the body-cavity on the right side of the buccal mass. It opens to the exterior by the genital pore. Distally the penis tapers to a thick-walled muscular tube, which carries at its end the prostate gland (fig. 6; *p, pro*). This gland has a bright-orange colour, while the penis is of a light-cream tint.

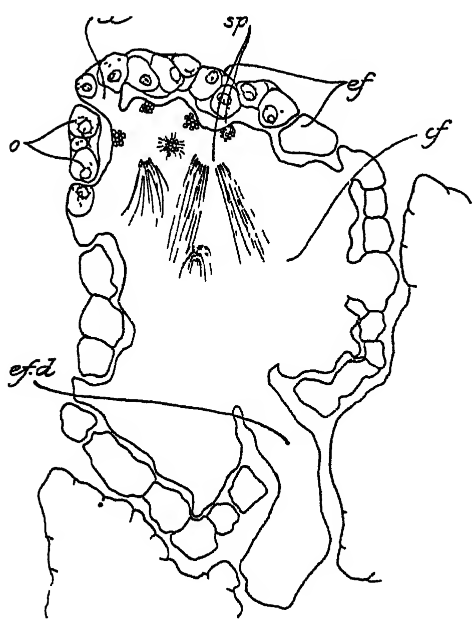

FIG. 7.—HERMAPHRODITE GLAND (TRANSVERSE SECTION); × 60.

cf, Central follicle, producing spermatozoa (*sp*); *ef*, external follicles, producing ova (*o*); *ef.d*, efferent duct leaving central follicle; *x*, passage from external to central follicle.

The various lobes of the hermaphrodite gland are made up of follicles. In each lobe there is a somewhat extensive central follicle surrounded by smaller follicles which are outgrowths from its walls (fig. 7; *cf, ef*). From the germinal epithelium of these outer follicles the ova arise, and in section each of these follicles contains one, two, or three ova—seldom more. From the epithelium of the large central follicle the

spermatozoa arise and develop in this follicle. Here are found spermatozoa in all stages of development, and when mature they pass from the follicle by means of an efferent duct to the main hermaphrodite duct. The outer follicles discharge their ova into the central one, and the ova thus reach the hermaphrodite duct in the same way (fig. 7; *cf. ef.d, x*). These ducts of the hermaphrodite gland are all ciliated. In the region of the seminal vesicle the dorsal side of the hermaphrodite duct loses its cilia, and becomes differentiated into a glandular structure of a beautiful rich dark brown. The cells of this gland are very large, and each contains a yellow secretion, which is distributed throughout the whole cell. In my sections of this region I found the lumen completely blocked up with spermatozoa.

There is no sharply marked-off albumen-gland discharging *into* the common duct, as in the case of *Aplysia* and *Helix*, but the common duct is itself very glandular, the posterior end especially; and the glandular walls of this duct, which become much folded, as we shall see, constitute the albumen-gland, so that the albumen-gland appears to form part of the duct in the reproductive system of *Siphonaria obliquata*. The lumen of this region of the duct is very complicated, and for the purpose of following out its anatomy I cut a series of sections through the whole of the duct, and by a study of these have been able to arrive at certain conclusions, which I propose to discuss in another paper.

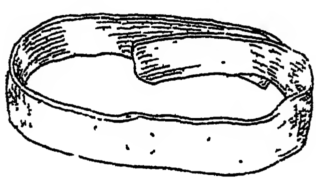

FIG. 8.—GELATINOUS RIBBON-LIKE MASS CONTAINING EGGS.
Represented as deposited by *Siphonaria.*

The eggs are deposited in a gelatinous material round the base of the mollusc, and are left attached to the rock in more or less circular ribbon-like masses (fig. 8). There are several eggs enclosed in each shell.

NOTES ON PRESERVING, ETC.

For preserving my specimens for dissection I used both formol and alcohol. The former has the advantage of preserving the natural colours, and this fact is especially useful in studying the nerve-collar, the ganglionic masses being orange-coloured. However, formol renders the tissues, with one exception, very hard; this exception is the glandular region of the common duct. In formol specimens I found this to swell up and become very brittle, so as to make it almost impossible to dissect. This organ preserves better in alcohol, and my drawings are from spirit specimens.

I tried several methods of killing *Siphonaria* so as to get the specimen well distended. I found this end was accomplished best by leaving freshly collected specimens for four or five days in a dish with a little sea-water in the bottom, then getting them gradually into fresh water, and thence into spirit or formol.

For fixing the tissues for histological purposes I used corrosive sublimate, corrosive sublimate plus 5 per cent. acetic acid, and glacial acetic acid. With all I obtained good results, but where I was able to make a fair comparison between them I found that in the majority of my preparations the last reagent gave me the best results.

For staining pieces of the tissues to be mounted whole I used alum carmine; for sections borax carmine and picro-carmine gave good results, except in the case of the genital duct, which I found difficult to get well stained: this organ requires three to four days' soaking in the stain. This difficulty arises in all probability owing to its size. In some preparations I used picro-nigrosine to show up the connective tissue, which it stains blue.

AFFINITIES OF SIPHONARIA OBLIQUATA.

In the original thesis I discussed at some length the affinities of *S. obliquata.* Results arrived at may be summarized briefly as follows:—

Opisthobranch Characters.

1. The spermoviduct is undivided throughout its length, a condition not characteristic of the Pulmonates. Some closely related genera, however—*e.g.*, *Gadinia* and *Amphibola*—have the duct divided.
2. The condition of the hermaphrodite gland.
3. The gill is possibly a modified ctenidium, but some authorities consider it a secondary structure.

Pulmonate Characters.

1. Large mantle-cavity, with small contractile respiratory pore.
2. Presence of a lung by which aerial respiration may be effected.
3. Presence of a pedal gland opening anteriorly between head and foot.
4. Its mode of life differs from that of Opisthobranchs.

In conclusion, I wish to acknowledge my indebtedness to Dr. Benham for many valuable suggestions in preparing the present paper for publication.

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EXPLANATION OF PLATES XXVIII, XXIX.

Plate XXVIII.

Fig. 1. Side view of *Siphonaria obliquata;* natural size. *a*, apex of shell; *bw*, body-wall; *h*, head; *ms*, muscular swelling of body-wall forming valve to close respiratory orifice; *r*, respiratory orifice; *sn*, siphonal notch; *s*, shell.

Fig. 2. Ventral view of *S. obliquata;* natural size (from a contracted spirit specimen). *f*, foot; *gp*, genital pore; *h*, head; *m*, mouth; *ms*, muscular swelling of body-wall forming a valve to close the respiratory orifice; *me*, free edge of mantle; *r*, respiratory orifice; *s*, shell.

Fig. 3. Ventral view of *S. obliquata;* natural size (from a large specimen well distended). *ll*, left lobe of head; *pg*, pedal gland; *p*, pore of pedal gland opening on to propodium; *rl*, right lobe of head. Other letters as in fig. 2.

Fig. 4. Anterior view of *S. obliquata.* Same specimen as represented in fig. 3; natural size. *a*, apex of shell; *e*, eye; *h*, head; *rl*, right lobe of head.

Fig. 5. Shell of *S. obliquata;* dorsal view; natural size. *a*, apex; *sn*, siphonal notch.

Fig. 6. Alimentary system; side view: digestive gland removed; × 2. *a*, anus; *bm*, buccal mass; *dg*, remains of left part of digestive gland, showing the two ducts entering the stomach close together; *dg′*, remains of right part of digestive gland; *fb*, floor of body-cavity; *f*, foot; *i*, intestine; *n*, nerve-collar; *oe*, oesophagus; *r*, rectum; *sg*, salivary gland; *st*, stomach.

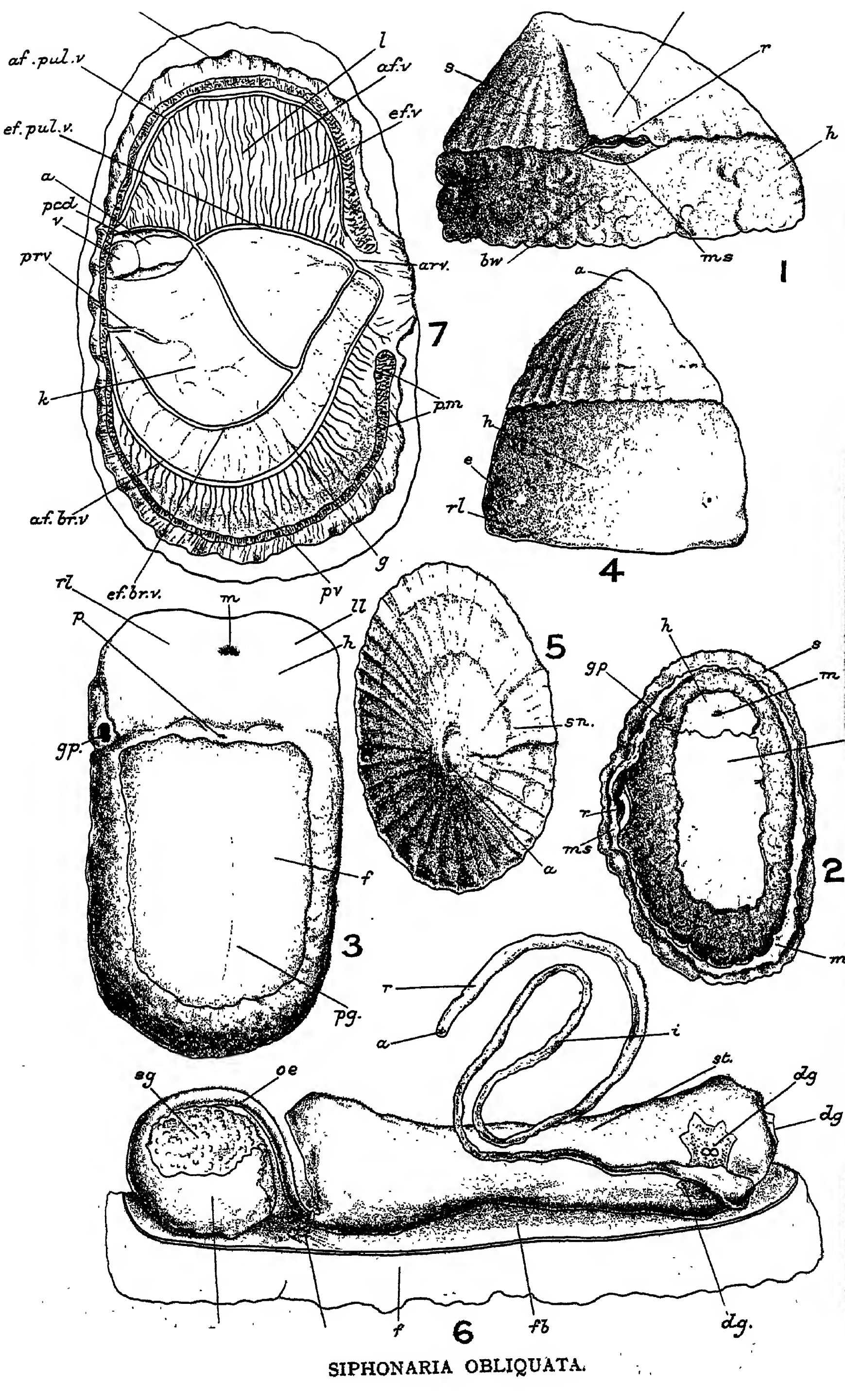
Fig. 7. Dorsal surface of *S. obliquata;* shell removed; × 2. *a*, auricle; *ar.v*, anterior renal vein; *af.v.*, an afferent vessel of lung; *af.pul.v*, afferent pulmonary vein; *af.br.v*, afferent branchial vein; *ef.v*, an efferent vessel of lung; *ef.pul.v*, efferent pulmonary vein; *ef.br.v*, efferent branchial vessel; *g*, gill; *k*, kidney; *l*, lung; *me*, mantle-edge; *pm*, pallial muscles; *pcd*, pericardium; *prv*, posterior renal vein; *pv*, pallial vessels; *v*, ventricle.

Plate XXIX.

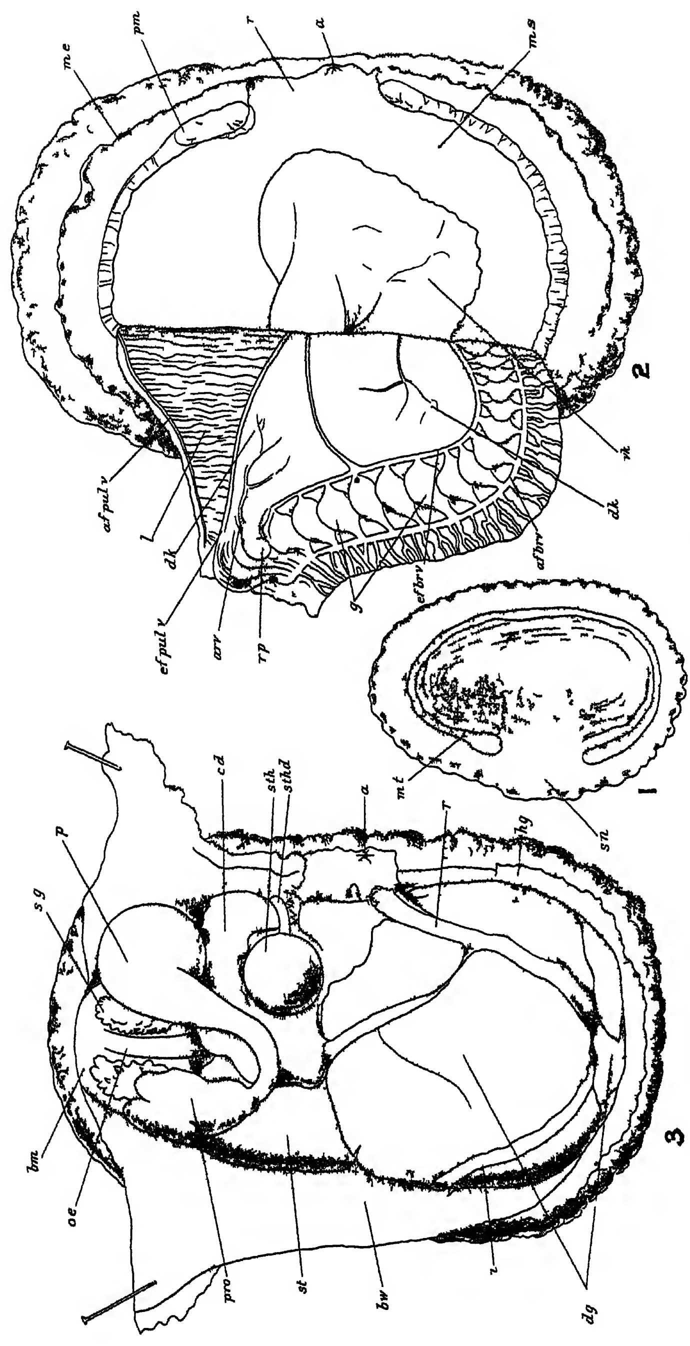
Fig. 1. Shell of *S. obliquata;* ventral view. *mt*, muscle impressions and tracts, showing successive position of the muscles as the animal grows; *sn*, siphonal notch.

Fig. 2. Dorsal view of *S. obliquata*, with pallial chamber opened and mantle turned to the left; × 2. *a*, anus; *af.br.v*, afferent branchial vein; *ef.pul.v*, efferent pulmonary vein; *g*, gill; *dk*, dorsal part of kidney; *l*, lung; *ms*, muscle-fibres of floor of pallial chamber; *me*, free mantle-edge; *pm*, pallial muscles; *rp*, renal papilla; *r′*, respiratory orifice leading into pallial chamber; *vk*, ventral part of kidney; *ef.br.v*, efferent branchial vein; *ar.v*, anterior renal vein; *af.pul.v*, afferent pulmonary vein.

Fig. 3. Body-cavity opened by cutting through the floor of the pallial chamber, showing internal organs *in situ;* × 2. *a*, anus; *bm*, buccal mass; *bw*, body-wall pinned aside; *cd*, common duct; *dg*, digestive gland; *hg*, hermaphrodite gland; *i*, intestine; *oe*, oesophagus; *p*, penis; *pro*, prostate; *r*, rectum; *sg*, salivary gland; *st*, stomach; *sth*, spermotheca; *sthd*, spermotheca duct.



SIPHONARIA OBLIQUATA.



SIPHONARIA OBLIQUATA

Mactra chrydaea

ART. LII.—*Two New Fossil* Mollusca.

By HENRY SUTER.

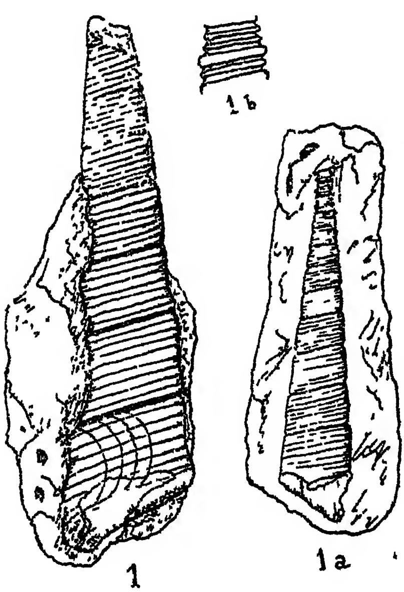
[*Read before the Otago Institute, 4th October, 1910.*]

Plates XXX, XXXI.

1. A NEW FOSSIL TURRITELLA.

Turritella semiconcava n. sp. Plate XXX.

Shell large, high and narrow, many-whorled, with 8 to 10 cinguli on the lower, slightly concave whorls, and a deep suture towards the base. *Sculpture*: The first few post-nuclear whorls have 4 equidistant spiral cords, the third much stronger than the others (fig. 1*b*); the following whorls have 5 subequidistant cinguli; gradually the number of cords increases on the whorls, the body-whorl of an adult specimen having usually 10 cords; the same sculpture is continued upon the base. *Spire* high, narrowly conic. *Protoconch* not seen. *Whorls* about 18 to 20 on a full-grown specimen, slowly and regularly increasing, flat on the upper whorls, lightly concave further down; the body-whorl narrowly rounded towards the flattish base. *Suture* on the upper part of the shell not much impressed, but gradually getting deeper approaching the base. *Aperture* subquadrate. *Outer lip* with a moderate broadly rounded sinus.



Figs. 1, 1*a*. *Turritella semiconcava.*
Fig. 1*b*. Post-nuclear whorl.

An adult specimen would have a diameter of 18–19 mm., and a height of about 95 mm; angle of spire, 11°.

Loc. — Mitchell's Point, Kaitangata Beach, Otago (Professor J. Park).

Professor James Park most kindly sent me specimens of this new *Turritella* for description, accompanied by the following remarks: "It occurs in thousands in thin calcareous tabular and lens-shaped masses in a greenish sandstone. Its associates are *Conchothyra parasitica*, *Chenopus* sp., *Belemnites lindsayi*, and many other forms. The Upper Kaitangata coal-bearing series are assigned to Upper Cretaceous."

Type in my collection.

Remark.—In sculpture this species is nearest to *T. cavershamensis* Harris (= *gigantea* Hutton), and in the concavity of the lower whorls it approaches *T. concava* Hutton, but it is decidedly distinct from both.

The photo reproduced on the plate was taken by Mr. A. G. Macdonald, and kindly sent to me by Professor Park.

2. A New Fossil Mactra.

Mactra chrydaea n. sp. Plate XXXI.

Shell small, ovate-trigonal, somewhat inflated, not gaping, with rather coarse concentric sculpture, equivalve, somewhat inequilateral, the anterior end a little shorter. *Beaks* slightly anterior, close together, prosogyrate, incurved, pointed. *Anterior end* convex, the dorsal margin lightly rounded, oblique. *Posterior end* subtruncated, very little arched, the dorsal margin convex and rather rapidly descending. *Basal margin* lightly convex, forming an obtuse angle with the posterior margin. *Posterior area* but ill defined, an obtuse keel descending from the beak to the postero-ventral angle. *Sculpture* consisting of well-marked concentric ridges, usually with deep sulci towards the base; under a lens rather distant radiate striæ can be seen, which are more distinct on the median part of the valves.

None of my specimens shows the *interior* of the valves, and the matrix is too hard to be removed without breaking the valves.

Length, 23 mm.; height, 19 mm.; diameter, 15 mm. (specimen figured). Length, 28 mm.; height, 22 mm.; diameter, 19 mm. (larger shell).

Type in my collection.

Loc.—It occurs in great abundance in the upper horizon of the Lower Pliocene blue sandy clays on the North Island Trunk Line, between Mataroa and Turanga-a-rere (J. Park).

Remarks.—This species is quite distinct from all the Recent and fossil New Zealand species of the genus. I wish to thank Professor J. Park for the specimens and the opportunity of describing them. The photo was most kindly provided by Mr. A. Hamilton, Director of the Dominion Museum.

Art. LIII.—*Maori Rock-engravings in the Kaipara District.*

By R. Buddle.

[Read before the Auckland Institute, 22nd November, 1910.]

Plate XXXII.

It is with no little diffidence that, upon the suggestion of Mr. Cheeseman, of the Auckland Museum, I venture to submit to the Institute this short account of some rock-carvings which I accidentally discovered on an ancient pa near the small settlement of Haranui, in the Parkhurst district, Kaipara.

The pa is within a mile of the famous old pa of Otakanini. It is a fine one, situated on a ridge, with the mud-flats of the harbour on one side and a swamp on the other. The whole ridge shows (as is so often the case) evidences of excavations, ditches, &c., while the main part, which is raised above the general level, is cut off by a deep ditch, and has an outwork at one corner which commands the most accessible flanks.

On the main terraces are several rectangular excavations which indicate that they were the sites of *wharepuni*, or "warm houses." It is on the side of one of these excavations that the designs are engraved in the soft sandstone. As there is a small modern cemetery just above, I was at first inclined to believe that they were of modern origin—that they were perhaps the work of some Maoris who had come there for the purpose of digging a grave; but, as the Natives whom I questioned pointed out, men engaged in such work were not likely to linger in the vicinity of a cemetery to waste

Maori Rock-engravings in the Kaipara District.

their time in such *mahi noa iho.* And upon examining the weathered surface and comparing it with that of the ditch, which still showed perfectly clearly the gouge-like impressions of the wooden *ko* with which it had been dug, I was convinced that the carvings were as old as the pa. Moreover, the cemetery is not more than ten or fifteen years old, and the condition of the engravings shows them to be very much older; and if they had been done in modern times there would certainly be traces of pakeha ideas—letters, or something of that sort. Furthermore, on the side of another similar excavation there was visible a trace of the same devices, and upon scraping away a considerable quantity of mould which had fallen in I found another series of very similar engravings. These, owing to the discoloration of the surface, I was unable to photograph.

The Natives of the neighbouring settlement of Haranui were able to furnish me with little information on the subject. They told me that the name of the pa was Oparuparu; that it belonged (as did all the old pas in this district) to the Waiohua or Ngaiwi Tribe; that it was taken by Ngatiwhatua, from the north, about the same time as Otakanini, but, while the latter was occupied by the conquerors, Oparuparu was destroyed.

The supposition that they are archaic inscriptions, such as have been so much talked of of late, may thus at once be dismissed. They are obviously and typically Maori, and their age cannot be more than one hundred to one hundred and fifty years.

As to their significance—if they have any—it is a mere matter of speculation. We read that the ancient Egyptians placed in the tombs of their dead the various articles supposed to be needed by the deceased in their after-life. At a later date they ceased to place there the actual articles, but instead painted or carved representations of them on the walls. This symbolism clearly was the first germ of the idea of a written language, and led naturally to the chronicling in picture-writing of the deeds of the deceased. The carvings and paintings which adorn the walls of the Maori *runanga*, or council-house, representing ancestors and their deeds, may perhaps be considered in the same light. The carvings in question are in an exactly similar position—namely, on the walls of a dwellinghouse. The only thing in the nature of a scheme which is visible in these carvings is the recurrence of the same device—namely, the conventional Maori face, which is the most prominent in both series. It will be noticed that these faces are of various sizes and proportions, and that some of them are curiously distorted. The only other symbols pertaining to man or human action are the two hands—if such they be—on the right side of the picture. Then several purely decorative designs are interspersed here and there, while the linear designs on the left are more like Moriori tree-carvings than anything else, but they are too much weathered to make anything of them.

This absence of any scheme or order is against their representing any events, for this implies a connection of ideas, and these ideas would naturally be set down in succession as they occurred to the worker. This want of order is also against their being purely decorative, since the Maori decorations are conspicuous for order and symmetry. Lastly, the fact that there are two series seems to indicate that they are not merely a *mahi noa iho*, or work of no account, done to pass the time.

There is only one other explanation which suggests itself to me. Mr. John Webster, of Hokianga, has described to me a ceremony witnessed by him, in which a *tohunga*, in consulting the oracle, drew unintelligible designs upon a piece of sandstone. This seems to me to afford a possible

Art. LIV.—*Reminiscences of Maori Life Fifty Years ago.*

By R. H. Matthews.

[*Read before the Auckland Institute, 22nd November, 1910.*]

1. Shark-fishing.

For the last twenty-five years the Maoris have lost all interest in the old-time institution of shark-fishing. Most of the *kaumatuas* (or elders) have passed away, and many of the traditional customs have gone with them. The younger generation devote their attention more to gum-digging and other pursuits, and appear to prefer tinned mullet and salmon to evil-smelling shark as a *kinaki* (relish).

Fifty years ago shark-fishing was considered and looked forward to as a national holiday by the Rarawas and all the surrounding *hapus*. The traditional customs and regulations were most strictly observed and rigidly enforced. The season for fishing the *kapeta* (dogfish) was restricted to two days only in each year. The first time was about full moon in January, and by preference during the night named in the Maori lunar calendar *rakaunui*, or two evenings after the full moon. This fishing was always by night. The second time of fishing, called the *pakoki*, was two weeks later, just after new moon (*whawha-ata*), and was always held in daylight. This closed the season for the year. Any one who killed a shark after this would be liable to the custom of *muru*, and would be stripped of his property. No one was permitted to commence fishing before the signal to start was given; a violation of this rule would lead to the splitting-up of the canoes of the offenders. So far as I can ascertain, the two days' restriction was a local custom, obtaining more particularly in Rangaunu Harbour, which was the great shark-fishing centre of the north, and it specially applied to the *kapeta*, or dogfish. Large sharks might be taken at any time in the open sea, but they were not to be killed inside the harbour for fear of frightening away the *kapeta*: "*Kei oho te kapeta.*"

At the time I am speaking of, the *mana*, or authority, over the *kopua* (the deep) was solely exercised by Popata te Waha, who had inherited it from his ancestors. It was he who issued the *panui*, or notice, of the date of the *maunga* (or catching), and who fired the signal-gun from his head-quarters at Okuraiti to notify the camps at Te Unahi and Pukewhau that sharks would be caught that night. Popata te Waha's *mana* over the *kopua* was acknowledged by all the surrounding tribes within a line extending from Taemaro (on the coast between Berghan's Head and Whangaroa) to Kohumaru, to Victoria Valley, Herekino, Ahipara, Parengarenga, and Rangiwahia, and all the numerous *kaingas*, or settlements, within this boundary. Maoris from all these places were represented at the great *maunga*. There would probably be a muster of not less than fifty canoes, each with an average crew of about twenty. This would make a total of at least a thousand, beside many that remained in camp cooking and drying *pipi*.

About a week before full moon in January, 1855, I received an invitation from one of the principal chiefs of Pukewhau to go shark-fishing with him. I gladly accepted this invitation, as I had heard a good deal about the curious customs attending the fishing, and wished to see the sport. He told me that I was to be one of his *kaiwhangai* (feeders). Later on I found that most of the wives accompanied their husbands as *kaiwhangai*, thus doubling the number of each man's catch.

For many days prior to the fishing crowds of Natives were to be seen going to Te Unahi on the Awanui River, Okuraiti, and Pukewhau, the three principal rivers flowing into Rangaunu Harbour. All were bent on having a good holiday, and on getting plenty of *kinaki* (relish)—*pipi* and fish; also looking forward to a plentiful supply of dried *mango* (shark) for *kinaki* during the winter.

We arrived at Pukewhau about noon, a ride of over ten miles across country. After a hearty snack I took a stroll through the village, which was humming like a swarm of bees, everybody being busily engaged in preparations for the *maunga*. Some of the old dames were scraping *muka* (flax-fibre), others were making it into twine by rolling the fibre on the calf of the leg with the palm of the hand. Some of the twine would be used for seizing the hooks; some for *pakaikai*, in lengths of about 3 ft., for tying on the bait. Altogether the *kainga* presented a busy and animated scene, full of life and good-humoured fun.

All along the *tauranga* (landing-place) were canoes of all sizes, from the large *wakataua* (war-canoe) to the small *tiwai*. Several of the *wakataua* were surrounded by a busy crowd of workmen: some were lashing on the bow-piece with its ornamental panel and figurehead, called a *pitau;* others were fastening on the tall elaborately carved *rapa* (stern-post); while others again were fitting and lashing the *rauoa* (top strake). This plank is called *oa* when free, but *rauoa* when fastened in position. Carefully selected leaves of *raupo* (*Typha*) were placed over the joints inside and outside, and were clamped firmly together by means of the *pokai*, or battens, which were then securely lashed by cords of three-plait flax-fibre. All holes were filled or caulked with *hune* (down from the seed of *Typha*). The *tauare*, or thwarts, were placed in position, and carefully lashed. A separate gang of workers was employed in making the *raho*, a movable platform on which the sharks are killed. This was fitted in sections under and between the thwarts, extending from stem to stern, and forming a kind of deck, under which there is room for stowing the sharks which may be caught. Standing apart from the rest was a particularly fine specimen of a war-canoe, named "Kaipititi," newly painted with *kokowai* (red ochre), and adorned with a beautifully carved figurehead and stern-post. The outside battens were dressed from end to end with the white feathers of the *toroa* and *karake* (albatros and gannet). While their elders were at work on the canoes the young people usually amused themselves with various games, such as wrestling, playing draughts on an extemporized board of flax-leaves plaited in squares on which shells and slices of potato were used for pieces, or, it might be, spinning loud humming-tops carved from the hard resinous core of the *kahikatea* tree (*kapara*) from which the sap had rotted away, or else some sport that happened to be fashionable at the time.

During the evening I strolled to a large *whare* where the *kaumatuas* and principal visitors were assembled. They were for the most part engaged in resnooding their hooks, and in discussing the merits of shape and bend. The shape of a hook was considered a very essential matter. Maoris in those days preferred their own make, short in the shank, never exceeding the breadth of three fingers, the standard measure. I handed over my hook to an old fellow, and asked him to overhaul it. It was given to me by the Aupouri chief Paraone, who was an acknowledged expert. I was told that it was not necessary to resnood it, as *kouaha* had been used on the seizing. *Kouaha*, I should say, is a poisonous gum which exudes from the bark of the *pukapuka* (*Brachyglottis repanda*), especially when the tree grows in a littoral

situation. It was formerly collected by the Maoris and preserved in *paua* shells. It was rubbed over the seizing of the hooks, which it not only preserved, but also prevented the shank of the hook from rusting. For snooding a shark-hook a four-plait is used, made of the fibre of the *tuara-whitu,* or bronzed-leaved *Phormium.* The cord is about ¾ in. in diameter and about 2 ft. 8 in. in length, and is tightly bound round with twine, except 6 in. at each end. It is then bent in the middle, thus forming a loop; the two loose ends are placed evenly round the shank, and firmly seized, leaving about 3 in. of the loose ends beyond, which are afterwards doubled back over the seizing, and tightly bound round with twine to protect the inner seizing from being cut by the teeth of the sharks. The seizing is continued along the rest of the loop, to make it as rigid as possible, for it is by this that the shark is securely held whilst being killed. Another plaited cord, about 2 ft. in length, but not seized, is made with a loop worked on each end. One end is slipped over the loop that carries the hook; the other is made fast to the fishing-line itself.

Next day several canoes, with nets, were sent down the river to catch mullet for bait, and also as food for the *kainga.** A visitor from Popata's camp arrived with the welcome news that the fishing was to be the next day, if our camp were well furnished with bait. (It was the custom to postpone the fishing until all the camps were well supplied). About midday the canoes returned with a big haul of mullet, which was at once served out. The fish were quickly cleaned, split into halves, the backbone taken out, and, if a large fish, cut into four parts. By this time the canoes had had a final overhauling, and were pronounced ready for sea. The large smooth oval stones used as anchors were now sorted out, netted over, and each supplied with 10 or 12 fathoms of rope. Others of the Maoris were employed in making short wooden clubs, called *timo,* with which the sharks are killed. The jawbone of a horse or an ox makes a most effective *timo,* and later on I saw several of these used on our canoe.

The report of the signal-gun fired at Okuraiti at once caused a commotion in the camp, followed by a shout of "*Tarahuna nga hangi*" (Light the oven-fires). The canoes were quickly launched, hooks and lines and bait put into *paros* and *poihewas* (small quickly made baskets) and stowed by each thwart, with the *timo* placed alongside. Soon after sunset the order was given to go on board, and off we started to the refrain of "*Huka ka huka*" (this is a light and rather quick stroke of the paddle, intended more to churn the water into foam rather than to gain speed). The canoes paddled along leisurely, reserving their strength for the great race and struggle later on. When we arrived at the rendezvous at Te Ureroa (roughly, about half-way to the Heads) we found the *kaupapa* (fleet) in position, facing the Pukewhau River. We took up our station, and kept it, as all the rest did, by aid of a *toko,* or long pole stuck in the mud, the stern of the canoe resting against a mangrove-tree. Here we waited for high water, the Natives in the meantime indulging in loud talking and laughter. The Maoris believed that the strong spring tides swept immense numbers of sharks into the harbour and far up the rivers and creeks, and that when the tide ebbed the returning sharks were intercepted by the fleet.

As the time of high water approached, the talking ceased, and there was a dead silence through the fleet. Presently our chief whispered, "*Kua*

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* *Papua* is the term used when a net is stretched across a creek or inlet just before high water, so that the fish are caught as they return with the ebb. When a net is simply hauled, it is called *kao*

whati te mata o te tai" (The tide has turned). Almost immediately after Popata stood up in his canoe and shouted out in a stentorian voice. "*Hua-kina*" (Charge). Then followed a most exciting race for the fishing-ground and the *mataika* (first fish). All through the fleet the Maoris were shouting "*Hoea, tiaia, toia, pehia, ana kumea.*" Roughly translated, these words are *hoea* (pull), *tiaia* (stick it in), *toia* (drag it along), *pehia* (press it down), *kumea* (haul it along). The last two mark deep, strong strokes of the paddle. The word *ana* is intended to make the stroke more strenuous; thus at the words *ana toia, ana pehia, ana kumea,* &c., every ounce must be put into the stroke. It was a brilliant moonlight night, and the whole fleet could be plainly seen paddling furiously for the channel. The shouting, yelling, and cheering, together with the noises that only the old-time Maoris could make, were indescribable.

As soon as the channel was reached anchors were let go, *ngeris* and *kokas* (waterproof cloaks made out of the prepared leaves of the *ti* (*Cordy-line*) were quickly tied round the waist, others were thrown over the shoulders, and then the ready-baited hooks were thrown overboard. Almost immediately, "*Kohi kohia*" (Haul in) was shouted from a canoe close to us, followed by a loud splashing and cries of "*Mataika*" (First fish). Then came the blows of the *timo* clubbing the snout, which is the vulnerable part of a shark. Presently one of our crew called "*Kohi kohia,*" for it was the invariable custom when any one hooked a shark to give warning, so that those sitting near could haul in or shorten their lines, and so save them from being bitten off or entangled. Eventually my turn came to give warning. I pulled the shark up to the gunwale, my friend then took charge and landed it on board by the old-time method known as *whakaepa*. The stiff looped cord is held about 4 in. above the shank of the hook with the left hand, whilst the right steadies and guides the shark as it is hauled in-board. At the critical moment it is promptly sat upon, and several smart blows with the *timo* close to the end of the snout soon quieten it. A corner of the *raho* is then lifted up, and the shark is passed to the bottom of the canoe. Within five minutes from the time of anchoring, and for the space of at least three hours, the sound of the *timo* could be heard incessantly all around us, accentuated by shouting and loud splashings. The scene was simply indescribable. All this time the fleet was gradually working down towards the mouth of the harbour, and sunrise found us anchored near the Heads. As the tide flowed we pulled up-river, and filled up at Te Mutu, a celebrated sharking-ground. The *rahos* were thrown overboard to make more room, and other preparations made for our return.

By half-tide the fleet, consisting of fifty canoes and two boats, were working up the harbour to the respective camps, apparently all deeply loaded. Any canoe had the right to continue work until high water, when the fishing closed till the *pakoki*, two weeks later. When a tiger-shark was hooked, or a large *toiki* (a much larger species than the dogfish), the lines and anchor were quickly hauled in, and the canoe paddled to the nearest sandbank. Sometimes the shark itself would tow the canoe into shallow water, and roll about in the endeavour to rid itself of the hook. It was quickly killed by spearing and by blows on the nose.

We landed at our camp before high water, and, now that the excitement was over, I felt stiff and tired, but was all right after a wash and a change into dry clothes. On returning to the river-side to see what was going on, I found that the sharks were all landed and laid out in separate heaps. I noticed that many of them had notches cut out of the fins and tails. This

was done to enable individual owners to identify their fish. The catch in our canoe totalled 180. (On referring to my diary, I find that on the 27th January, 1875, no less than 265, or about 6 tons in weight, were caught on one large canoe). The cleaning of the sharks had now commenced. The *pane* (heads) were first removed; then a strip was cut following the curve of the belly. This strip, called the *whauaro*, was considered a great delicacy. The bodies were hung by the tails to a *tarawa* (a tall scaffolding), or thrown across a top rail, belly side up. There they remained until thoroughly dried by the sun and wind. The heads and *tapiki* (entrails) were generally left on the scene of operations. In a day or two the stench would be intolerable. The livers were thrown into a large funnel, made of green flax-leaves with a lining of soft fern-leaves, and suspended in a rough framework of tea-tree. Large stones were then heated and placed on them, and the oil was caught in calabashes. Surplus livers were put into the stomachs of the sharks, and hung up in the sun until the oil exuded from them. The total number of sharks caught by the fleet, including those taken at the *pakoki* held a fortnight later, was about seven thousand, an average of about sixty-five per canoe for each of the two trips.

The *kapeta*, or dogfish, is well known to be viviparous. During the month of December and up to the middle of January the ova are generally perfect, the embryo very rarely to be seen. Towards the end of January the embryo is plainly visible, and by the end of February it is perfectly developed, although in many instances still attached to the remains of the ovum. At that stage they are about 4 in. long, but increase rapidly in size. Mr. C. Puckey informs me that on one occasion while fishing in Houhora Harbour towards the end of March he caught a *toiki* 10 ft. long. On opening it he found seventeen young sharks, each 18 in. long, which swam briskly away when put in the water. When fishing at Rangaunu Heads on the 2nd April one of my crew caught a dogfish, and on ripping it open eight or ten fully developed sharks 8 in. long dropped into the water and swam away. Captain Wilson informs me that when fishing for *hapuku* off the Watchman in October a great number of sharks were caught, and on cutting one open for bait no less than forty-one perfectly developed sharks were found in it, each about 7 in. in length. On the 11th November Captain Wilson took a fishing-party to the North Cape, when many sharks were caught. One that was cut open had a number of young sharks about 6 in. in length. I think it is probable that sharks carrying fully developed young keep in blue water, and rarely, if ever, go into the harbours or estuaries. I am inclined to believe that sharks breed more than once a year.

A few general notes on the subject of sharks may prove to be of interest. The dried sharks were stacked in food-houses, or *whatas*, just like so much firewood. Narrow strips were cut and cooked on hot stones, and beaten with a *paoi* (pestle for pounding fern-root) to soften the flesh. Sometimes the cooking was done in a *hangi*, or steam-oven. In this case the flesh was cut in chunks, and not pounded.

Shark-oil was used in a variety of ways and for a number of purposes. It was mixed with *kokowai* (red ochre) for painting war-canoes, *urupas*, and the ornamental portions of the principal houses, as well as the carved work about the pas. The *urupa* was a graveyard, or, more correctly, a carved monument, usually standing on two posts, erected in memory of some great chief. They were usually beautifully carved, and very *tapu*. The oil was also used to anoint the bones of their deceased friends after the ceremonial scraping, or *hahunga*. In this case it was often mixed with a

small quantity of *kokowai*, just enough to give the bones a light tint. As a cosmetic for the body and hair, the oil was used either with or without an admixture of *kokowai*, and it was often scented with *kopuru* moss, with *raukawa* (*Panax Edgerleyi*), *manakura* (*Melicytus micranthus*), or some other scented shrub.

The *koinga* shark was closely preserved at Ahipara. This is a small species, rarely exceeding 3 ft. in length. Its flesh was considered more delicate and better eating than that of the *kapeta*. The liver produced a finer oil, not nearly so rank, and was held in high esteem for anointing purposes. This species has two dorsal fins, and in front of each is a strong bony tusk, or spine, which gives it the distinctive name of *koinga* (a sharp point). The front tusk is about 2½ in. in length, and the hinder one a little shorter. The livers were cut into halves and put into calabashes, heated stones being placed on the top, to try out the oil.

The teeth of the *mako* shark were greatly prized. They were called *ngutukao*, and were worn suspended from a hole bored in the lobe of the ear. If sold they always fetched a high price, and I saw two bullocks given for a pair of medium size in 1855. In the north the *mako* is usually caught at or near the North Cape. The canoe pulls out to the *mako* ground, when a lot of fish is thrown overboard as a *poa* (attraction). The *mako*, which is a tame fish, is attracted alongside by the bait, when a strong *mahanga* (noose) is passed over its head below the dorsal fin and then pulled tight around the small of the body. It was never caught with a hook, for fear of injuring the teeth. Four teeth only were considered of special value, two in the upper and two in the lower jaw. The best-shaped teeth had the points bent slightly outwards, the others were bent sideways more or less according to their position. The *mako* attains a length of from 7ft. to 10 ft. While mostly found near the North Cape, stray specimens are occasionally met with between Rangaunu Heads and Cape Karikari. We once captured a medium-sized fish in this locality, and lost another—a large one—owing to the line breaking.

In the "Handbook of the Fishes of New Zealand," 1886, by R. A. A. Sherrin, the author states that the *mako* of the Maoris is considered to be identical with the *Lamna glauca*, or tiger-shark. But the tiger-shark known in the north as such is an entirely different fish: it is a good deal larger, growing from 10 ft. to 12 ft., and bigger round the body; it is also much more powerful and more difficult to handle; the teeth also are different, being very large and of a triangular shape, like those of a crosscut saw, instead of the slender curved form of those of the *mako*.

In the same work, referring to the dogfish, the statement occurs that "the ground-shark (dogfish) deposits eggs, usually two at a time, enclosed in horny cases several inches long, not unlike those of the skate." This is evidently a different fish, as our dogfish, or *kapeta*, is well known to be viviparous.

2. PIGEON-SNARING.

The bush-pigeon (*Carpophaga novae-zealandiae*), known in the north by the Maori name *kukupa*, is fast becoming scarce. It has always been held in the highest estimation by the Maoris on account of the peculiarly delicate flavour of the flesh. As late as the "fifties" the *kukupa* was found in countless numbers—all the forests were swarming with them. At that time the Maoris could only get 1 lb. of gunpowder per man during a year. They were very chary of using this, and made it spin out by using very reduced charges, whilst the old people, including many that I knew well, still used the spear, to which I shall refer later on. Since that time, owing

to the removal of the restriction on the sale of powder (in 1857) and to the increased number of white settlers, and perhaps also to the spread of diseases brought by introduced birds, the *kukupa*, once so plentiful, is now every season becoming more difficult to find. Before the introduction of guns, and for many years after owing to the restriction referred to above, the chief methods of taking the *kukupa* were by the spear and noose.

The spear named *tarchi* was of great length, the best being made of *kapara*, the gum-preserved core found in some decayed *kahikatea* and *rimu* trees after the sap-wood had rotted away. An old Maori once described to me the method of making them. Very great care was taken to select a piece of *kapara* so straight in the grain that when struck at one end with a *toki* (stone axe) and a wedge driven in it would split open from end to end. The long pieces thus obtained were roughly trimmed and taken to the *kainga*, where, by weeks and weeks of patient chipping and scraping they were made round and smooth When completed they were about 25 ft. in length by $1\frac{1}{2}$ in. in diameter. A piece of the hard black substance found in an old dry *ponga* (tree-fern), about 10 in. long, $\frac{5}{8}$ in. wide, and $\frac{3}{8}$ in. thick, was smoothed, sharpened to a point, with one or more barbs worked on it, and then neatly bound to the end of the shaft. If accidentally broken, it was quickly and easily replaced. Sometimes the spears were made of *manuka*, in shorter lengths, two of which, from 12 ft. to 15 ft. in length, were bound together, one end being pointed and barbed. Occasionally the spear-points were made out of the bone of the sperm-whale.

Now for the mode of hunting the *kukupa* and using the spears. One or more trees of the *miro* (*Podocarpus ferrugineus*), loaded with fruit, and regularly visited by the birds, were selected. Several long poles were placed against the tree, or an adjacent one by preference, to serve as a ladder, up which the hunter could easily and quickly climb. If required, a cover was fixed in the tree to conceal the Maori from the birds. All being ready, he climbed up, got under his cover, and waited patiently. Presently a flock of, say, twenty pigeons would settle in the *miro*. Amongst the flock there is always a quarrelsome cock bird, generally in poor condition, called a *tu-te*, continually disturbing the others (*tu-te* is literally a person who nudges another with the elbow). The *tu-te* is always the first bird speared, so that the other birds may feed undisturbed. The spear is rested on a branch exactly in line with the birds, and is pushed up very gently until the point is within 18 in. of a bird. It is then suddenly thrust up, so that the bird is transfixed. The spear is then quickly lowered, and the bird killed and dropped to the ground. The man goes on quietly working, and in a short time bags the greater part of the flock.

When pigeons are noosed, the method usually followed is as under: The top branches of trees frequented by the birds are lopped or broken off, and straight rods of *manuka* tied across in several directions. To these the nooses were fastened. Great numbers of pigeons were caught in this manner. Nooses were also placed on the margin of a forest-creek where pigeons were in the habit of drinking. Sometime a *kumete* (trough), hollowed out of a log 6 ft. to 8 ft. long, and filled with water, was put in a suitable place, and nooses tied over and around it.

Another method was adopted for taking small birds. A long stick, called *pae*, was tied in a slanting position about 4 ft. above the ground; shelter or concealment was provided near it, behind which a man stood armed with a long straight *manuka* stick called *whiu* (literally a whip). With a leaf in his mouth, usually the leaf of the *turutu* (*Dianella intermedia*), he would make a "peeping" sound resembling the call of young birds. Fan-

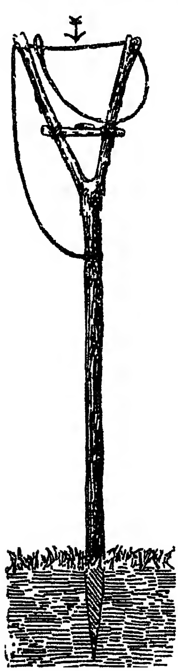
tails, bell-birds, and other small species would be attracted by the noise, and settle on the *pae*. A rapid stroke of the *whiu*, sweeping from end to end of the *pae*, would dislodge and kill these birds. An old man once told me that in his younger days he had often taken a kitful of *korimakos* in this way in a single day. The *pae* was also employed for taking the *kaka* parrot. Here a tame bird was often used as a decoy; when that was not available the cry of the bird was very cleverly imitated.

One occasion, many years ago, I travelled in company with Mr. Puckey to Mangamuka by the old Maori track crossing the western shoulder of Maungataniwha. When we arrived at the bottom of Whatatawha, and when we were passing along the low foothills, we met a party of Maoris who had been spearing pigeons. Each man had a goodly number of birds slung round him, wrapped up in *nikau* leaves. There was not a gun amongst them. We passed through the rich valley of Hunuhunua, and arrived at Pongaheka, a *kainga*, or village, at the boat-landing on the Mangamuka River. On approaching the river we saw a line stretched tightly along the edge of the water, which was covered from end to end with an immense number of nooses. On inquiry we were told that it was a *ta-iki* for catching pigeons. The birds, it was said, were always very thirsty when feeding on *miro* berries. We also noticed a *taraire* tree near the river which had had its upper branches removed and nooses so placed that a pigeon could hardly settle on it without being caught.

Thus with spear and noose the old-time Maori was able to keep his larder plentifully supplied with the delicious *kukupa*.

3. TRAPPING OF HAWKS.

For catching hawks a trap called a *tara-haha* was used. A straight *manuka* pole 6 ft. to 8 ft. in length, and about 2 in. in diameter, with two strong opposite branches at the top, making a kind of fork, was selected. The lower end was sharpened, for convenience in sticking it in the ground. The prongs or forks were cut off at the top, leaving them about 18 in. long, and were neatly smoothed and rounded, with a transverse notch cut across the top. A piece of straight stick about 9 in. long was fastened across the prongs about a third of the distance from the base of the prongs for the purpose of spreading the prongs, and the bait was tied to this cross-piece. A noose was then placed resting on the notches on the top of the prongs, the lower end of the noose hanging just above the bait. The end of the cord above the noose was fastened a little distance below the fork. The accompanying sketch of a *tara-haha* ready for use will give a better idea of the construction of the trap than any description. All being ready, the *tara-haha* was firmly stuck in the ground with the opening between the prongs facing the wind, the bait tied to the cross-piece, and the noose placed in position on the wind side of the bait. (A hawk always swoops down on his prey head to the wind, and flies off in the same manner—head to wind.) In flying away the hawk is caught by the noose, generally by both wings, which are consequently held close to the body, thus lessening the risk of breaking the noose.



Art. LV.—*The Verse-unit.*

By Johannes C. Andersen.

[*Read before the Philosophical Institute of Canterbury, 2nd November, 1910.*]

Part I.—Lyric Measures.

Section I.

1. Next to the stress-unit, the smallest uniform aggregation of parts is the verse. This normally contains eight stresses, or their temporal equivalents, and is usually divided, when printed, into two equal parts. Each part of a verse so divided is commonly known as a line.

2. From a casual examination of poetry, the length of the line—that is, the number of its stress-units—would appear to be quite arbitrary. It would appear that it rested with the poet himself to decide whether a line should contain one stress-unit or eight. Whilst the line thus appears to be, and really is, under his control, it is otherwise with the verse. The length of the verse is determined by a natural law, and the poet has not yet lived who has broken this law with impunity. The length of a line may range from one duple stress-unit, as in Herrick's

(1.) Thus I
Passe by,
And die:
As one
Unknown,
And gone:

to eight triple stress-units, as in Tennyson's—

(2.) Fame blowing out from her golden trumpet a jubilant challenge to
Time and to Fate;
Slander, her shadow, sowing the nettle on all the laurell'd graves
of the Great.

("Vastness," stanza 11.)

It will not be denied that the poet is at perfect liberty to print the verse as he pleases; so that Coleridge's verse will by one poet be printed as two lines—

(3.) The fair breeze blew, the white foam flew,
The furrow followed free;

("Ancient Mariner," part ii.)

—whilst by another it will be printed as three—

(3*a*.) The fair breeze blew,
The white foam flew,
The furrow followed free;

And what Browning prints as two lines—

(4.) How sad and bad and mad it was—
But then, how it was sweet!

("Confessions," last stanza.)

—Herrick might print as five,—

(4*a*.) How sad
And bad
And mad
It was—
But then, how it was sweet!

So far, then, as printing is concerned, the poet has absolute liberty to do as he pleases, or as the printer pleases.

3. It is to be observed, however, that the line had assumed definiteness, and maintained that definiteness, whatever it was, before the poet could have any thought of printing at all; at the time, in fact, when the poems were recited or sung. So absolute was this definiteness that on the introduction of printing it required no ingenuity, no labour, on the part of the printer to set down the poems in a way that has not to this day changed in any essential particular. In many instances where he had manuscript before him he would no doubt be guided by the scribe, who, if the lines were run on, would show the divisions and subdivisions by periods and colons, or by some other equivalent device.

4. At the time of the mingling of the Saxon and Norman races the form of English poetry underwent a great change, passing from the alliterative stave of the skald to the metrical verse of the minstrel. That such change did not take place without the struggle attendant on all changes is well shown in the "Vision of Piers Plowman," a poem which is a connecting-link between the two forms. The type of the new form is seen in the "Metrical Romances," which were built up of verses of eight stresses, not yet divided into stanzas. M. Leon Gautier thinks that these verses, divided into four-stressed lines, were derived from a Latin form, the "iambic dimeter":—

Forti sequemur pectore.*

The tracing of the absolute origin of these lines must be accomplished before the final word can be written, but it need not concern us here, seeing that the English form was not derived from the Latin, but from the already evolved French type. It was in this French eight-stressed verse that a notable developmental change took place when the metre became acclimatized in England.

5. Professor Saintsbury has noted† that the verse of the "Metrical Romances" showed a constant tendency to drop a unit; and this tendency has resulted in the metre becoming seven-stressed, the seventh stress being followed by a pause. The new metre, once evolved, became one of the most popular and persistent forms in English poetry, which it still pervades, forming the basis of all the lyrical metres. It will therefore be of interest to see if any cause can be assigned to the fact that the new metrical form was a verse of eight stresses, and that the eight stresses shortened to seven stresses and a pause.

6. Any regular stanza will serve as illustration: take Burns's—

(5.) Ye banks and braes o' bonie Doon,
    How can ye bloom sae fresh and fair?
How can ye chant, ye little birds,
    When I'm sae weary, fu' o' care!
Thou'll break my heart, thou warbling bird,
    That wantons thro' the flowering thorn!
Thou minds me o' departed joys,
    Departed never to return.

("The Banks o' Doon," stanza 1.)

These verses, being modern, are thus printed, each verse being split into two lines of four stresses each. It will readily be noted, however, that

* *H. E. Berthon*, "Specimens of Modern French Verse," p. xv of Introduction.
† "History of English Prosody," vol. i, p. 248, and Appen. vi, p. 406.

every line is not complete in itself, but that they go naturally in couples; that every two lines are in fact one long verse :—

(5*a*.) Ye banks and braes o' bonie Doon, how can ye bloom sae fresh and fair ?
How can ye chant, ye little birds, when I'm sae weary, fu' o' care !

Every verse is now a complete sentence, consisting of two clauses, occupying a line each. It was because each line was a clause that the Romance metre was so easily resolved into two parts, and was written in couplets. Even in the couplet form the complete relation of the two lines is evident :—

(6.) Wild as the scream of the curlew,
From crag to crag the signal flew.
Instant, through copse and heath, arose
Bonnets and spears and bended bows;
On right, on left, above, below,
Sprung up at once the lurking foe;
From shingles grey their lances start,
The bracken bush sends forth the dart,
The rushes and the willow-wand
Are bristling into axe and brand,
And every tuft of broom gives life
To plaided warrior arm'd for strife.
("The Lady of the Lake," canto v, section ix.)

The same holds as regards all Lyric stanzas ; they are composed of integral parts, each integral part being a verse of eight stress-units, or their temporal equivalents—that is, if the verse contain only seven or six stress-units, it will be found to contain also one or two pauses, equivalent to the units dropped. Take the following examples :—

(7.) The raging rocks,
And shivering shocks,
Shall break the locks
Of prison-gates ;
And Phibbus' car
Shall shine from far,
And make and mar
The foolish fates.
("Midsummer Night's Dream," I, ii.)

(8.) We join the throng
Of the dance and the song,
By the whirlwind of gladness borne along ;
As the flying-fish leap
From the Indian deep,
And mix with the sea-birds, half asleep.
("Prometheus Unbound," IV, line 83.)

(9.) By the fair and brave
Who blushing unite,
Like the sun and wave
When they meet at night ;

By the tear that shows
When passion is nigh,
As the rain-drop flows
From the heat of the sky ;
("Lalla Rookh.")

(10.) Weep, weep, weep, and weep,
For pauper, dolt, and slave !
Hark ! from wasted moor and fen,
Feverous alley, stifling den,
Swells the wail of Saxon men—
Work ! or the grave !
(*C. Kingsley*, "Alton Locke's Song.")

(11.) My Peggy speaks sae sweetly,
Whene'er we meet alane,
I wish nae mair to lay my care,
I wish nae mair of a' that's rare.
My Peggy speaks sae sweetly,
To a' the lave I'm cauld:
But she gars a' my spirits glow
At wawking of the fauld.

(*A. Ramsay*, song 1 of 'The Gentle Shepherd.')

(12.) By whom was David taught
To aim the deadly blow,
When he Goliath fought,
And laid the Gittite low ?
No sword nor spear the stripling took,
But chose a pebble from the brook.

(*W Cowper*, Olney Hymn, iv.)

All are divided into groups of eight-stressed verses, dropped units being represented by pauses:—

(7*a*.) The ra/ging rocks/, and shi/vering shocks/, shall break/ the locks/ of pri/son-gates/ ;

(8*a*.) We join/ the throng/ of the dance/ and the song/, by the whirl/wind of glad/ness borne/ along/ ;

(9*a*.) By the fair/ and the brave/ who blu/shing unite/, like the sun/ and wave/ when they meet/ at night/;

(10*a*.) Weep/, weep/, weep/, and weep/, for pau/per, dolt/, and slave !/ /.
Hark !/ from wa/sted moor/ and fen/, fe/verous al/ley, sti/fling den/,

(11*a*.) My Peg/gy speaks/ sae sweet/ly, /whene'er/ we meet/ alane/, /
I wish/ nae mair/ to lay/ my care/, I wish/ nae mair/ of a'/ that's rare, .

(12*a*.) By whom/ was Da/vid taught/ /to aim/ the dead/ly blow/, /
When he/ Goli/ath fought/, /and laid/ the Git/tite low ?/ /
No sword/ nor spear/ the strip/ling took/, but chose/ a peb/ble of/ the brook/.

This division shows the pauses that are felt instinctively in reading, and shows that each verse has the full value of eight stress-units. The relation of the variations, one to another, will be examined more at large in a subsequent paragraph.

7. Remembering that when the full eight-stressed verse developed poetry was commonly sung or recited, it will be evident that great regard would naturally be had to facility of delivery. In speech, a sentence consists of as much thought as may be conveyed readily in one breath : the more broken a complete thought is in its utterance the less forcible it becomes ; and it follows that the most incisive thought is that which, the matter of thought being equal, can be distinctly uttered in one breath. The most incisive thoughts are those which appeal most deeply to the emotions, and a sentence will therefore be shorter or longer as it is more or less emotional. The earliest poetry is almost purely emotion, bare of all ornament of rime, alliteration, metre, or even rhythm. The first ornament was metaphor ; then came rhythmic expression. As the people emerged from barbarity, evolving music and dance with its poetry, a finer rhythmic sense developed. In the Maori language poetry may be studied in many stages, from unrhythmical laments and love-chants to perfectly rhythmical war-songs, some of which were on the verge of becoming rimed and metrical, when their development was rudely interrupted by civilization. It would appear as if the dance of motion and gesture was the force controlling the rhythm of poetry and music : once the rhythm was established, it developed

independently of the dance. In rhythmic poetry the sentences were of varying lengths; in metrical verse they tended to assume a uniform length—an average of the length of rhythmic or emotional sentences: in other words, the average length of a breath.

8. This average had been established when the metre of the "Metrical Romances" was introduced into England; but that the evolution of the verse-form was still in progress is evident from the fact that the eight-stressed verse showed a tendency, already referred to, in the direction of discarding a unit at the end of the verse. Can any reason be seen for this tendency? During the early days of the metre in England the Church wrote "Lives of the Saints" in the same popular measure as the "Metrical Romances." This measure still pervades Church hymns, and these hymns have in a most important particular faithfully preserved the old metre. On examining the Church hymns, ancient and modern, it will be noted that they are distinguished chiefly as being in three "measures" or metres—L.M., long measure; C.M., common measure; and S.M., short measure—these measures being respectively eight-, seven-, and six-stressed verses, or verses of sixteen, fourteen, and twelve syllables. If the music of the hymns be examined it will be found that almost every verse of two lines, whether L.M., C.M., or S.M.—more, that verse of even five stresses—is sung to sixteen crotchets or sixteen syllables—the Romance verse: the Church has, in its music, preserved the old form. Is not this a most significant fact; and is it not a revelation of the extraordinary power of the unobstrusive law, in obedience to which poets have moulded their ever-varying, yet ever typically constant, Lyric measures? Now, I can vouch for it that at least one not too highly trained Church choir was taught to sing the sixteen crotchets, usually written as eight minims, in one breath; a hurried breath or gasp was taken, and the next sixteen crotchets were sung, and so on. We have here a perpetuation of the old methods of modification—a remnant of the processes of evolution—the only vital modern addition being the harmony of the music—the elaboration of melody. The gasp would be more noticeable in the voice of the poet, unaccompanied by musical instrument as often as not; and the dropping of the final unit in the eight-stressed verse was prompted by the necessity for drawing a more leisured breath after the delivery of each metrical sentence. The breath was taken easily and silently, so that whilst the eighth unit had no articulate existence, it was still present temporally—that is, so far as its time was concerned, the verse was unaltered, the resulting seven-stressed verse being temporally equal to the eight-stressed. This equality is quite apparent when the two verses occur together, as in the old ballad of "King Cophetua and the Beggar-maid":—

(13.) The blinded boy, that shootes so trim,
  From heaven downe did hie;
He drew a dart and shot at him,
  In place where he did lye:
Which soone did pierse him to the quicke,
And when he felt the arrow pricke,
Which in his tender heart did sticke,
  He looked as he would dye.
"What sudden chance is this," quoth he,
"That I to love must subject be,
Which never thereto would agree,
  But still did it defie?"

(Stanza 2.)

Here the pauses following "hie," "lye," and "dye" are palpably longer than those following "pricke" and "be," the reason being, of course, that the verses ending with the two latter words have retained the eighth unit, whilst those ending with the three former have dropped that unit :—

(13*a*.) The blin/ded boy/, that shootes/ so trim/, from hea/ven downe/ did hie/; /
He drew/ a dart/ and shot/ at him/, in place/ where he/ did lye/: /
Which soone/ did pierse/ him to/ the quicke/, and when/ he felt/ the ar/row pricke/,
Which in/ his ten/der heart/ did sticke/, he looked/ as he/ would dye/. /
"What sud/den chance/ is this/," quoth he/, "that I/ to love/ must sub/ject be/,
Which ne/ver there/to would/ agree/, but still/ did it/ defie?" / /

This fact is still more evident in stanzas of the following type, an exceedingly popular one both among poets and readers :—

(14.) We played at love in Mulga town,
And O, her eyes were blue!
We played at love in Mulga town,
And love's a game for two.
If three should play, alack-a-day!
There's one of them will rue,
Dear Heart!
There's one of them will rue.

(*W. H. Ogilvie*, "In Mulga Town," stanza 1.)

This stanza could quite well be rounded off at the first "rue," when it would be composed of three ordinary Ballad verses of seven stress-units each. The addition of the "Dear Heart!" however, converts the last line of these stress-units into one of four, again followed by one of three :—

(14*a*.) If three should play, alack-a-day!
There's one of them will rue, dear heart!
There's one of them will rue.

It simply means that the pause at the end of the line containing only three stress-units is filled, making it equal to the line preceding. There is a telescoping, as it were, of an eight-stressed and a seven-stressed verse, the former resulting when the first and second lines of (14*a*) are taken together, the latter when the second and third are taken together. The special point to be observed is that the pause following the seven-stressed verse is of sufficient duration to admit of its place being taken by an ordinary stress-unit of two syllables in the present example, or three syllables in a triple metre, and when its place is so filled the pause altogether disappears. The inference is that whenever a verse containing only seven stress-units occurs the pause by which it is followed is simply a gap from which sound has been dropped, and into which sound may at any time be replaced. In other words, the verse of seven stress-units, or Ballad verse, is merely a variation of the verse of eight stress-units, the Romance verse. The pause may not always be exactly equal to the dropped unit, for a pause being unable to assert itself as articulate sound is able, it has a tendency to collapse on itself as it were—to shorten unequally. It nevertheless always retains the power to expand so as to admit the restoration of the dropped unit, should such restoration be desired.

9. The full verse of eight stress-units will hereafter be called the Romance verse, from the fact that it formed the metre of the French romances; the verse of seven stress-units will be called the Ballad verse, from the fact that it forms the vital metre of the common English ballad. The Romance metre, too, is considered as being the parent of the Ballad.

10. The Ballad metre has two lesser brethren, also probably sprung from the Romance, though not on English ground. The first of these may be called the Nibelungen metre, from the fact that it forms the metre of the great German epic, the "Nibelungen Noth." It is an important ballad-metre both in Germany and in Denmark. It is easy to see the relation existing between Ballad and Nibelungen metres: a verse of each is contained in Christina Rossetti's "He and She":—

(15.) Should one of us remember,
  And one of us forget,
I wish I knew what each would do—
  But who can tell as yet?

This forms the typical metre of "Horatius"; and in thirty-nine out of the forty-five stanzas of that poem the two metres mingle. The Nibelungen has a most distinctive lilt, and its peculiarity is due to the fact that the *stressed* syllable of the fourth unit has been dropped:—

(15*a*.) Should one/ of us/ remem/ber, / and one/ of us/ forget/,
I wish/ I knew/ what each/ would do/—but who/ can tell/ as yet?/

For variations in the Nibelungen metre one must turn to the great German epic itself as to a treasure-house. The following are noted:—

(16.) *a*. We are/ in an/cient sto/ries / won/ders ma/ny told/
b. Fair/ without/ a ble/mish, / her gra/cious bo/dy was/,
c. Of fes/tival and/ rejoi/cing, / of wee/ping and/ complai/ning,
d. Who al/so in/ his youth/ful days/ great ho/nour of/ten won/.
e. For whom/ must ma/ny good/ly war/riors lose/ both bo/dy and breath/.
f. Of no/ble he/roes' stri/vings must/ ye e'en now/ to won/ders hear/ken.
g. I will/ of both/ avoid/ me, / that I/ from mis/chance may/ be spared/.
h. How sor/row / to true/ love / oft/ at length/ is bared/;
i. So yet/ to thee/ will God/ allot/ a good/ly knight/ of stur/dy limb/.

These variations all occur in the first Adventure, containing nineteen stanzas of four verses each; and besides these, there are many verses varied internally—that is, at other places besides the line-ends and verse-ends. It will therefore be evident that the metre, whilst retaining its peculiar character, is infinitely varied. In *d*, *e*, and *f* above it swells to full Ballad; in *i* it swells to full Romance; in *g* we have a Romance verse with a Nibelungen unit, an exceedingly rare verse in British poetry. Burns has a striking example in "Sae flaxen were her Ringlets"—

(17.) Sae flaxen were her ringlets,
  Her eyebrows of a darker hue,
Bewitchingly o'er-arching
  Twa laughing een o' bonie blue.
Her smiling, sae wyling,
  Wad make a wretch forget his woe!
What pleasure, what treasure,
  Unto those rosy lips to grow!
Such was my Chloris' bonie face
  When first that bonie face I saw,
And ay my Chloris' dearest charm—
  She says she lo'es me best of a'!

(Stanza 1.)

It is seen by the concluding verses that the whole is a Romance stanza; it will be noted, too, that verses three and four are parallels to quotation *h* so far as the opening is concerned—an opening used by very few British poets outside Scotland. Tennyson has a happy combination of the three verses Nibelungen-Romance, true Nibelungen, and true Romance in his song in "The Miller's Daughter"—

(18.) It is the miller's daughter,
  And she is grown so dear, so dear, (Nib.-Rom.)
That I would be the jewel
  That trembles in her ear: (Nib.)
For, hid in ringlets day and night,
I'd touch her neck so warm and white. (Rom.)

—which is divided,—

(18*a*.) It is/ the mil/ler's daugh/ter, / and she/ is grown/ so dear,', so dear/,
That I/ would be/ the jew/el / that trem/bles in/ her ear/: /
For, hid/ in ring/lets day/ and night/, I'd touch/ her neck/ so warm/ and white/.

The swelling of the Nibelungen to this Nibelungen-Romance has almost the effect of the Alexandrine swell in the Spencerian stanza:—

(19.) Now came the lovely maiden, as morning steals in rose
Forth from sullen shadows; then slipped their many woes
From men's faint hearts, new gladdened to have old aches dispelled;
He saw the lovely maiden, her grace and her splendour he beheld.
(Adventure v, stanza 17.)

This swelling, whilst common in the epic, has nevertheless a strange sound to English ears, and one would rather suppose the Nibelungen metre to have sprung from the Ballad than from the Romance direct. This can only be determined by tracing the Nibelungen to its source; but it is only necessary, so far as this analysis is concerned, to show the practical identity of the two metres, Nibelungen and Ballad.

11. The second brother of the Ballad is the metre known as the Alexandrine, so called from its being the metre of an old French romance whose subject is Alexander.* It is a still further shortening of the Ballad metre; it drops the whole of the fourth unit—the unit from which the Nibelungen drops only the stressed syllable. Its relation to the Ballad is also easily seen:—

(20.) In court whoso demaundes
  What dame doth most excell;
For my conceit I must needs say,
  Fair Bridges bears the bel.

Upon whose lively cheeke,
  To prove my judgment true,
The rose and lillie seem to strive
  For equall change of hewe.
(*Gascoigne's* "Praise of the Fair Bridges.")

Divided, this reads,—

(20*a*.) In court/ whoso/ demaundes/ / what dame' doth most/ excell/;
For my/ conceit/ I must/ needs say/, fair Brid/ges bears/ the bel/.

The relation to the full Romance is shown in quotation (12*a*):—

When he/ Goli/ath fought/, / and laid/ the Git/tite low?/ /
No sword/ nor spear/ the strip/ling took/, but chose/ a peb/ble from/ the brook/.

The three metres, Alexandrine, Ballad, and Romance, occur side by side in J. Montgomery's "Night":—

(21.) Night is the time for rest;
How sweet, when labours close,
To gather round an aching breast
The curtain of repose,
Stretch the tired limbs, and lay the head
Down on our own delightful bed!

* "Roman d'Alexandre," by Alexandre de Bernay, twelfth century.

(21*a*.) Night/ is the time/ for rest/; / how sweet/, when la/bours close/,
To ga/ther round/ an a/ching breast/ the cur/tain of/ repose/, /
Stretch/ the tired limbs/, and lay/ the head/ down/ on our own/
delight/ful bed!/

The Alexandrine in (21) is made Nibelungen by substituting "resting" for "rest," and Ballad by adding "and peace" to "rest":—

(21*b*.) Night/ is the time/ for rest/; / how sweet/, when la/bours close/,
Night/ is the time/ for rest/ing; / how sweet/, when la/bours close/,
Night/ is the time/ for rest/ and peace/; how sweet/, when la/bours close/,

No dislocation of metre ensues; the pause is simply filled; and is not that an indication that the pause is occasioned by syllables having been dropped? The pause is evident enough when the Alexandrine occurs with other metres; when, however, a poem is entirely in Alexandrines it is not quite so apparent. The following is from song xxvi in Drayton's "Polyolbion":—

(22.) And of these archers brave, there was not any one
But he could kill a deer, his swiftest speed upon,
Which they did boil and roast in many a mighty wood,
Sharp hunger the fine sauce to their more kingly food.
Then taking them to rest, his merry men and he
Slept many a summer's night under the greenwood tree.
From wealthy abbots chests and churls abundant store,
What oftentimes he took he shar'd amongst the poor:
No lordly bishop came in lusty Robin's way,
To him, before he went, but for his pass must pay:

As already said, the pause, which tends to shorten, may not have, and most probably has not, the full value of the dropped unit; it is, nevertheless, potential to expand for the reception of such unit should necessity demand it.

In the old Romances these Alexandrines are at times written as couplets, as was also more generally the full Romance verse. Of verses written at length, Warton says,* "And some critics may be inclined to suspect, that the verses which we call Alexandrine, accidentally assumed their form merely from the practice of absurd transcribers, who frugally chose to fill their pages to the extremity, and violated the metrical structure for the sake of saving their vellum." In France the Alexandrine has been highly developed; in England it is used principally in its simplest form—a verse of two parts each containing three stress-units, and divided by a pause. It is here wished to show merely that this simpler form is closely connected with the Ballad.

12. Whilst Alexandrine and Nibelungen are closely related to Ballad, there seems to exist between them a curious antipathy, except when they are interwoven in short stanzas. In the following they blend well:—

(23.) I loved a lass, a fair one,
As fair as e'er was seen;
She was indeed a rare one,
Another Sheba Queen.
But fool as then I was,
I thought she loved me too:
And now, alas! she's left me,
Falero, lero, loo.

(*Wither*, "I Loved a Lass.")

In the "Nibelungen Noth," on the other hand, whilst all manner of variations, and combinations of Nibelungen verses with Ballad and Romance

* "History of English Poetry," section 1 (page 30 of Ward, Lock, and Tyler's reprint in one volume).

occur, Alexandrines are almost absent—as though the two national metres were, like the two peoples, mutually inimical. In the first eight Adventures* of the great epic—that is, in 544 stanzas, containing 2.176 verses—there are only five Alexandrines, viz.:—

(24.) *a.* E'en so/ did she/ excel/ / all good/ly dames/ thereby/;
(Adv. v, st. 19, v. 3.)

b. Dame U/te there/ also/, / the king/ly wife/ sat/.
(Adv. v, st. 54, v. 3.)

c. Though not/ so much/ for thee/ / I serve/ or love/ of thine/,
(Adv. vi, st. 71, v. 1.)

d. Full soon/ Brunhild/ the fair/ / did on/ a state/ly robe/;
(Adv. vii, st. 29, v. 1.)

e. And mark/ aright/ thou/, / what thou/ dost hear/ me ut/ter.
(Adv. vii, st. 68, v. 2.)

Of these, the first example is perhaps better scanned,—

(24*a.*) *a.* So stood/ she / before/ them / and good/ly dames/ excelled/;

this being a common type of verse in the epic (see example (16) *h*). Again, *d* might be scanned :—

(24*a.*) *d.* Brunhild/ / the fair/ one / donned quick/ly a state/ly robe/;

but this is doubtful, as, were such intended, "Brunhild" would probably have been written "Brunhilde," as in—

(25.) The love/ly / Brunhil/de, / she/ who bore/ a crown/
(Adv. x, st. 26, v. 3.)

This means that four, or at most five, Alexandrines are admitted in a total of 2,176 verses, a proportion so small, considering the large amount of variation the Nibelungen verse takes, as to suggest a foreign form. One conclusion may perhaps be drawn with some certainty—that is, whilst the Nibelungen appears to be a variation, by shortening, of the Ballad, the Alexandrine is not a variation, by shortening, of the Nibelungen. It may not be demonstrable, but it will possibly be found that the Alexandrine, being a peculiarly French form, developed directly from the Romance metre in France, as the Ballad developed from the Romance in England. Warton† quotes a "Norman-Saxon poem" in which there are traces of Nibelungen in a body of Alexandrine verse. He was of opinion "that a pause, or division, was intended in the middle of every verse; and in this respect its versification resembles also that of 'Albion's England,' or Drayton's 'Polyolbion,' which was a species very common about the reign of Queen Elizabeth."

13. If, however, we turn to modern Danish poetry, we may find perfect examples of the blending of Nibelungen, Alexandrine, and Ballad in poems whose metre is basically Nibelungen. The following examples are from Winther's series "Woodcuts" :—

(26.) *a.* When on/ the o/cean fell/ / the sun's/ low e/ven beam/,
And our hou/ses and/ church stee/ple then/ were bathed/ in ro/sy gleam/,
Upon/ the door's/ board mos/sy / his fol/ded arms/ he laid/,
Whilst down/ the vale/ below/ him, /his glance/ unwea/ried strayed/.
(Steffen og Anne, st. 2.)

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* German edition by Dr. Gustav Pfizer: Stuttgart und Tübingen, 1843.
† "History of English Poetry," section 1 (page 16 of Ward, Lock, and Tyler's reprint in one volume).

b. To mor/row af/ter ser/mon-time/ to Nor/retown/ I go/,
From mo/ther's sis/ter learn/ing / to cro/chet lace/ and sew/ ;
If you/, my best/ Johan/, / will thi/ther walk/ with me/,
Kis/ses I/ will give/ you, / it may/ be two/, or three/.
(Johan og Lise, st. 10.)

c. The voice/ cried loud/ly, " Pe/ter Hald !/ ere ear/ly day/ shall break/,
Arise/, your bo/dy clothe/, / your shel/tered home/ forsake !/
Where trolds/ have dwelt/ in hol/low oak/ a trea/sure glim/mers bright/,
Your for/tune if/ my war/ning / you scorn/ not / this night/.
(Christen og Lene, st. 7)

d. She po/lishes/ her bed/, / nor snow/ could brigh/ter be/,
Upon/ the mill-/door comes/ a tap/ping,—one/, two/, three !/
In steps/ Sir Lyk/ke's ser/vant, / he lifts/ his cap/, polite/,
" And will/ ye spare/ a space/ / for my/ sack here/ to-night ? "/
(Svend og Inger, st. 21.)

Viewing these examples, and many isolated examples in British verse, there can be no doubt that the Alexandrine proper is divided by a mid-pause into two equal parts—that it is, in fact, no more than a variation of the Romance metre.

14. A well-known stanza may for a moment be examined :—

(27.) What objects are the fountains
Of thy happy strain ?
What fields, or waves, or mountains ?
What shapes of sky or plain ?
What love of thine own kind ? What ignorance of pain ?

This will now be seen to fall readily into two Nibelungen verses and one Alexandrine :—

(27*a*.) What ob/jects are/ the foun/tains / of/ thy ha/ppy strain ?/
What fields/, or waves/, or moun/tains ? / What shapes/ of sky/ or plain ?/
What love/ of thine/ own kind ?/ / What ig/norance/ of pain ?/

Again, take the version of Psalm viii by the Earl of Surrey :—

(28.) But yet among all these I ask, " What thing is man ? "
Whose turn to serve in his poor need this work Thou first began.
Or what is Adam's son that bears his father's mark ?
For whose delight and comfort eke Thou has wrought all this work.
I see Thou mind'st him much, that dost reward him so :
Being but earth, to rule the earth, whereon himself doth go.
From angels' substance eke Thou mad'st him differ small ;
Save one doth change his life awhile ; the other not at all.
The sun and moon also Thou mad'st to give him light ;
And each one of the wandering stars to twinkle sparkles bright.
The air to give him breath ; the water for his health ;
The earth to bring forth grain and fruit, for to increase his wealth.

This quotation is taken from " Preliminary Remarks on the Olney Hymns " in the Rev. T. S. Grimshawe's 1851 edition of Cowper, where it is followed by the ominous remark, " Sir Thomas Wyatt versified the seven Penitential Psalms, and died in 1542." On first reading the above example the end-construction of the first verse causes a stumble : and it will be re-read either as—

(28*a*.) But yet/ among/ all these/ I ask/, " What/ thing/ is man ? "/

or

(28*b*.) But yet/ among/ all these/ I ask/, " What thing/ is/ man ? "/

making it of the same type as Moore's verse—

But there's no/thing half/ so sweet/ in life/ as love's/ young/ dream/.

—a construction that will at once be discarded as ridiculous in this instance. In two verses only in the whole quotation does the poet himself offer a clue to the reading :—

I see Thou mind'st him much, that dost reward him so :

and

The air to give him breath ; the water for his health ;

In fact, every odd verse of the quotation is an Alexandrine, whose mid-pause *must* be observed if the metre is to run smoothly :—

(28c.) I see/ Thou mind' t/ him much/, / that dost/ reward/ him so/ :
Be/ing but earth/, to rule/ the earth/, whereon/ himself/ doth go/.

and so of the opening :—

(28d.) But yet/ among/ all these/ / I ask/, " What thing/ is man ? "/
Whose turn/ to serve/ in his/ poor need/ this work/ Thou first/ began/.

15. This paused Alexandrine is called in French " Alexandrin classique," and all French verse in this metre took the classical form until the time of V. Hugo, when a " vers trimètre " was introduced, which was an Alexandrine broken into *three* equal parts by *two* pauses."

16. One stanza of Shelley's " Skylark " has been given, No. (27), and it has been shown that the stanza consists of two Nibelungen verses followed by an Alexandrine ; but the construction of other stanzas in Shelley's poem is different :—

(29.) Hail to thee, blithe spirit !
Bird thou never wert,
That from heaven, or near it,
Pourest thy full heart
In profuse strains of unpremeditated art.

If this stanza be divided in the way No. (27) was divided—

(29a.) Hail/ to thee/, blithe spi/rit ! / bird/ thou ne/ver wert/,
That/ from heaven/, or near/ it, / pour/est thy/ full heart/
In pro/fuse strains/ of un/ /preme/dita/ted art/.

—we again obtain two Nibelungen verses and one Alexandrine ; but in the Alexandrine a word, " unpremeditated," is divided by a pause ; and whilst many readers would probably make some pause on the " un "—not necessarily, be it again noted, equal to a full unit—others would make no pause whatever, producing an *unpaused Alexandrine.* In every verse of Shelley's poem, excepting the verse ending the first stanza above quoted, the pause can be made naturally, though all readers will not necessarily make it ; and it might be supposed that Shelley's verse is a solitary anomaly. But turning from the " scorner of the ground " to the sometime " scorner of metre," Browning, we read such verses as,—

(30.) But, when you would dissect the structure, piece by piece,
You found, enwreathed amid the country product—fleece
And feather, thistle-fluffs and bearded windle-straws—
Some shred of foreign silk, unravelling of gauze,
Bit, may be, of brocade, mid fur and blow-bell-down :
Filched plainly from mankind, dear tribute paid by town,
Which proved how oft the bird had plucked up heart of grace,
Swooped down at waif and stray, made furtively our place
Pay tax and toll, then borne the booty to enrich
Her paradise i' the waste ; the how and why of which,
That is the secret, there the mystery that stings !
(" Fifine at the Fair," section ix, l 7 *et seq.*)

Without the mid-pause, can anything but prose be made of the first three verses of this quotation? In the fourth, fifth and sixth, the eight and tenth verses the pause is plainly indicated; and, once the indication is given, the pause is made involuntarily, even where there is no indication, and rhythmic harmony becomes metrical harmony. A parallel structure is seen in Tennyson's verses:—

(31.) A million emeralds break from the ruby-budded lime
In the little grove where I sit—ah, wherefore cannot I be
Like things of the season gay, like the bountiful season bland,
When the far-off sail is blown by the breeze of a softer clime,
Half-lost in the liquid azure bloom of a crescent of sea,
The silent sapphire-spangled marriage-ring of the land?

("Maud," section IV, stanza 1.)

Taken from their context, are not the two concluding verses simply beautiful rhythmic prose—prose in structure but poetry in thought? Much of Poe's weird rhythmic prose is on the verge of metre: "They sigh one unto the other in that solitude, and stretch towards the heaven their long and ghastly necks, and nod to and fro their everlasting heads." The sentences—

(32.) And stretch towards the heavens   their long and ghastly necks,
And nod to and fro   their everlasting heads

—become true Alexandrines when the pause is inserted; but would they be considered Alexandrines without the pause? I think not: they would be deemed rhythmic, but not metrical. The question arises, how far may a similar conclusion be applied to matter that is set out as verse? The pause is more certainly subverted when the metre becomes triple:—

(33.) I was a child, an' he was a child, an' he came to harm;
There was a girl, a hussy, that workt with him up at the farm,
One had deceived her an' left her alone with her sin an' her shame,
And so she was wicked with Harry; the girl was the most to blame.

* * * * *

But he anger'd me all the more, an' I said, "You were keeping with her,
When I was a-loving you all along an' the same as before."
An' he didn't speak for a while, an' he anger'd me more and more.
Then he patted my hand in his gentle way, "Let bygones be!"
"Bygones! you kept yours hush'd," I said, "when you married me!"

(*Tennyson*, "The First Quarrel," st. iv, xiii.)

The true ballad form of the first stanza may be seen in Poe's "Annabel Lee":—

(34.) I was a child, and she was a child,
In this kingdom by the sea:
But we loved with a love that was more than love—
I and my Annabel Lee.

To conform to the lyric measure Tennyson's verse should be paused:—

I/ was a child/, an' he/   / was a child/, an' he came/ to harm/;

and this pause is indicated in many verses of the poem:—

There/ was a girl/, a hus/sy,   / that workt/ with him up/ at the farm/,

Thus paused, the poem is brought back to the perfect Lyric measure of the pure Ballad; and I cannot believe but that every verse, however rugged, floated, in the poet's mind, upon this pure Ballad metre.

17. The apparently absolute subversion of the pause, exemplified in the first verse of No. (33), is yet more strikingly illustrated in Browning's metrically remarkable poem "Pheidippides":—

(35.) First I salute this soil of the blessed, river and rock!
Gods of my birthplace, daemons and heroes, honour to all!
Then I name thee, claim thee for our patron, coequal in praise—
Ay, with Zeus the Defender, with Her of the aegis and spear!
Also, ye of the bow and the buskin, praised be your peer,
Now, henceforth and forever,—O latest to whom I upraise
Hand and heart and voice! For Athens, leave pasture and flock!
Present to help, potent to save, Pan—patron I call!

Archons of Athens, topped by the tettix, see, I return!
See, 'tis myself here standing alive, no spectre that speaks!
Crowned with the myrtle, did you command me, Athens and you,
"Run, Pheidippides, run and race, reach Sparta for aid!
Persia has come, we are here, where is She?" Your command I obeyed,
Ran and raced: like stubble, some field which a fire runs through,
Was the space between city and city: two days, two nights did I burn
Over the hills, under the dales, down pits and up peaks.

Into their midst I broke: breath served but for "Persia has come!
Persia bids Athens proffer slaves' tribute, water and earth;
Razed to the ground is Eretria—but Athens, shall Athens sink,
Drop into dust and die—the flower of Hellas utterly die,
Die, with the wide world spitting at Sparta, the stupid, the stander-by?
Answer me quick, what help, what hand do you stretch o'er destruction's brink?
How,—when? No care for my limbs!—there's lightning in all and some—

Rough-hewn as this verse appears, beneath its ruggedness flows the perfect smoothness of the lyrical ballad! Though the measure is not, as Mr. Symons says in his "Introduction," an "invention of Mr. Browning's," no other British poet has used it with Browning's magnificent effect. As will be noted on reading the quotation, the verses are greatly varied, and great variation is a characteristic of a new as well as of an old type. In the new, however, the variations are new, unfamiliar, and in many cases isolated; whereas in the old the variations have become fixed, and are as familiar almost as the type itself. The latter is the case with the variations of the ballad: the strangeness of many of Browning's verses in "Pheidippides" is of itself an indication of the newness of the metre. The most obtrusive characteristic of the poem is the breaking-up of the verses, which are triple Alexandrines, into three parts; instead of the usual middle pause of the Alexandrine, these verses have two pauses, thus breaking into three approximately equal parts:—

(35*a*.) 1. Archons of Athens, topped by the tettix, see, I return!
2. Gods of my birthplace, daemons and heroes, honour to all!
3. Over the hills, under the dales, down pits and up peaks.
4. Present to help, potent to save, Pan—patron I call!

The characteristic unit of the poem is evidently the "choriamb," a Greek unit of four syllables, of which the first and last bore the stress. This is a unit which Browning himself has previously used:—

Kentish Sir Byng stood for his King, bidding the crop-headed Parliament swing;

The verse of "Pheidippides" breaks off at the "crop" of this example, with what loss to the sweep of metre the ear will at once detect. The choriamb of (35) is still further varied by receiving a feminine ending, reducing the length of the pause between every two units, as may be seen

by comparing No. (35*a*) 1 with No. (35*a*) 3. This pause is further reduced in the third verse of No. (35) :—

35*b*. Then/ I name thee/, claim thee/ for our pa/tron, coe/qual in praise/

and the verse is still fuller in—

(35*c*.) 1. Ay, with Zeus the Defender, with Her of the aegis and spear!
2. Now, henceforth and forever,—O latest to whom I upraise

A new variation is developed in these two verses :

(35*d*.) 1. Archons of Athens, topped by the tettix, see, I return!
2. Now, henceforth and forever,— O latest to whom I upraise

Compare this with No. (16) *b*, a Nibelungen verse-

(35*e*.) 1. Now/, henceforth/ and fore/ver,— / O la/test to whom/ I upraise/
2. Fair/ without/ a ble/mish, / her gra/cious bo/dy was/,

—and it is at once seen that Browning's verse is a triple Nibelungen verse, the pause in the middle showing where a stressed syllable has been dropped. Again, couple No. (35*e*) 1 with the verse immediately following in the quotation—

(35*f*.) Now/, henceforth/ and fore/ver,— / O la/test to whom/ I upraise/
Hand/ and heart/ and voice!/ / For A/thens leave pa/sture and flock!/

—and a paused triple Alexandrine is seen following the Nibelungen, as in No. (26) *b*. Again, couple together the third and fourth verses of the third stanza :—

(35*g*.) Razed/ to the ground/ is Ere/tria—/ but A/thens, shall A/thens sink/,
Drop/ into dust/ and die/—the flower/ of Hel/las ut/terly die/,

Here the pause in the second verse is not due to a dropped syllable as in the first; so that whereas the first verse is Nibelungen, the second is not Alexandrine, but *full Ballad*. Were the pause supposed to represent a dropped unit the result would be—

(35*h*.) Drop/ into dust, and die/— / the flower/ of Hel/las ut/terly die/,

—a verse of eight units. Read the third stanza to its conclusion, and any doubt of the verse being full Ballad at once vanishes :—

(35*i*.) Drop/ into dust/ and die/—the flower/ of Hel/las ut/terly die/,
Die/ with the wide/ world spit/ting at Spar/ta, the stu/pid, the stan/der-by ?/
An/swer me quick/, what help/, what hand/ do you stretch/ o'er destruc/tion's brink ?/
How/,— when ?/ No care/ for my limbs !/—there's light/ning in all/ and some/—

It is evident that the sweep of the Ballad measure has been with the poet throughout: the poem is in Alexandrines, and the natural, and consequently more musical, manner of reading it will consist in observing the mid-pause of each verse ; for the rest, the metre will assert itself :—

(35*j*.) First I salute this soil of the blessed, river and rock!
Gods of my birthplace, daemons and heroes, honour to all!
Then I name thee, claim thee for our patron, coequal in praise—
Ay, with Zeus the Defender, with Her of the aegis and spear!
Also ye of the bow and the buskin, praised be your peer,
Now, henceforth and forever,— O latest to whom I upraise
Hand and heart and voice! For Athens, leave pasture and flock!
Present to help, potent to save, Pan—patron I call!

The pause is merely a sustaining of the sound of the word preceding that pause; it need be but slight, yet it works a magical change, making of

an irregular metre one perfectly regular and familiar; it destroys the obtrusively harsh "clickety-clack," "clickety-clack" of the unbroken choriambs.

18. One other fact concerning this dominant metre of "Pheidippides" may be noted: verses such as

Archons of Athens, topped by the tettix, see, I return!

are, when the mid-pause is disregarded, nothing more or less than parallels of the "Alexandrin trimètre" referred to in paragraph 15. It is difficult to compare French and British metres, even when of the same type, as in this instance, seeing that the stresses of French verse are almost free from the definite, though not rigid, laws to which British verse is subject. It is most interesting, however, to observe that parallel developments are taking place in huge bodies of verse, dissimilar in general nature, but similar in their fundamental laws.

19. The unpaused Alexandrine, then, by which is meant the Alexandrine without *mid*-pause, would appear to be an unnatural variation, for which but short life might be prophesied did not the art of printing forbid. Irregularly paused Ballad verses, too, confusing as they do the lyric flow, cannot live—except in print. Of this kind is Browning's "Reverie":—

(36.) Power is known infinite:
  Good struggles to be—at best
Seems—scanned by the human sight,
  Tried by the senses' test—
Good palpably: but with right

Therefore to mind's award
  Of loving, as power claims praise?
Power—which finds nought too hard,
  Fulfilling itself all ways
Unchecked, unchanged: while barred,

Baffled, what good began
  Ends evil on every side.
To Power submissive man
  Breathes "E'en as thou art, abide!"
While to good "Late-found, long-sought,

"Would Power to a plenitude
  But liberate, but enlarge
Good's strait confine,—renewed
  Were ever the heart's discharge
Of loving!" Else doubts intrude.

(Stanzas 16–19.)

This poem was published in 1889, the year of Browning's death, in the volume "Asolando: Fancies and Facts," and it is even more defiant of the restraints of metre than the most unruly of his previous poems. These restraints, or natural laws, consist of number of units to a verse, and position of the two principal pauses in the verse. As regards the former law, it is so palpable, though unwritten, that very few poets disregard it. The full Romance verse must contain no more than eight stress-units; if it contain less, it becomes Ballad, Nibelungen or Alexandrine, and each of

* See remarks on this metre in French poetry, by H. E. Berthon, in "Specimens of Modern French Verse," p. xxvi.—London, 1899.

these variations must adhere to its number of units at peril of its existence. Less palpable is the latter law, the position of pauses; a pause, having no sound, and being thus liable to lengthening or shortening at the will of the reader, is unable to assert itself in the aggressive manner of audible parts, and is liable to be disregarded; but to tuned ears the pauses are as full of harmony as the articulations, and divide those articulations into harmonious groupings. In the full Romance verse there is the natural pause, the breath-pause, following every eighth stress: there is a mid-pause, not so marked, following the fourth stress, dividing the full verse into two equal parts :—

(37.) Ye banks and braes o' bonie Doon,   how can ye bloom sae fresh and fair ?

As in the course of the arrow shot upwards there are two parts, the ascent and the descent, with a slight hover in the air as the arrow turns, so in the full verse there are two parts, and a slight dwelling at the union of the two parts that welds but does not crush them together. Besides these two principal pauses the verse may, and usually does, contain minor pauses, whose positions are entirely optional, depending as they do on the syntactical construction :—

(37*a*.) How can ye chant,   ye little birds,   when I'm sae weary,   fu' o' care !

So, too, of the Ballad verse :—

(38.) There blew a drowsy, drowsy wind,   deep sleep upon me fell;

Here the end-pause, dividing the verses, is much more marked than in the Romance verse, the reason being that a full unit has been dropped to allow of easy breath being taken. The consequence is that the verse is divided into two *unequal* parts by the mid-pause, which still falls, as in the Romance verse, after the fourth stress. Should it fall after the third stress, the sense of balance is lost, as in No. (35*h*).

Drop into dust and die—the flower of Hellas utterly die,

Here the "utterly" sounds superfluous, the reader being strongly inclined to read the verse :—

(39.) Drop/ into dust/ and die/—   / the flower/ of Hel/las die/,

The true mid-pause should fall after "flower"—

(39*a*.) Drop/ into dust/ and die/—the flower/   of Hel/las ut/terly die/,

—when it becomes an ordinary Ballad verse. In the poem "Pheidippides" it comes especially strangely because it occurs among Alexandrines, whose mid-pause naturally falls after the third stress; but, as observed in (35*h*), if this Alexandrine mid-pause—the *equivalent*, it will be remembered, of a dropped unit—be observed, a verse of *eight* units, a full Romance verse, results—

Drop/ into dust/ and die/—   / the flower/ of Hel/las ut/terly die/,

—which is reminiscent of the Romance swell occurring in the Nibelungen metre of the German epic: see No. (19), the last verse :—

He saw/ the love/ly mai/den,   / her grace/ and her splen/dour he/ beheld/.

Drop/ into dust/ and die/—   / the flower/ of Hel/las ut/terly die/,

Supposing it to be a full Romance verse, it is the solitary Romance verse in the poem. One rather supposes it to be an ordinary Ballad verse, with

the mid-pause misplaced; a principal pause, in short, has been placed in the position of a minor pause, and hence the confusion. As contrast, two examples may be quoted.—

(40.) *a.* I see Thou mind'st him much, that dost reward him so:
Being but earth, to rule the earth, whereon himself doth go.

b. Razed to the ground is Eretria— but Athens, shall Athens sink,
Drop into dust and die— the flower of Hellas utterly die,

A probable origin of such unbalanced Ballad verses is more fully discussed in paragraph 1 of Section II.

20. It was said in the last paragraph that the full Romance verse must contain no more than eight stress-units. This is no arbitrary but a natural law, implicitly obeyed by the poets. On the perception of the law poetry emerged from the rhythmical to the metrical form, and since that emergence the law has been obeyed—intuitively, it may be, but the more perfectly perhaps for that very reason. One may search the garden of British poesie for violation of the law in vain, until the latest garden of Tennyson is entered, when the failing hand of the gardener was no longer able to check the growth of weeds:—

(41.) Will my tiny spark of being wholly vanish in your deeps and heights?
Must my days be dark by reason, O ye Heavens, of your boundless nights,
Rush of Suns, and roll of systems, and your fiery clash of meteorites?

"Spirit, nearing yon dark portal at the limit of thy human state,
Fear not thou the hidden purpose of that Power which alone is great,
Nor the myriad world, His shadow, nor the silent Opener of the Gate."
("God and the Universe.")

The thought is starlike in its splendour of bloom: was the flower called a weed? At least, around the briar to which the rose has ranked lingers a sweetness intense as the subtlest odour of the rose; and it must not be forgotten that the rose was, in the first place, a foster-child of the briar. But, shutting his eyes to the beauty of the thought, is not every reader conscious of a certain inharmony in the metre? What is the cause of it?—of what does the thorn of the briar consist? Approach the flower from another side:—

(41*a*.) Will my tiny spark of being vanish in your deeps and heights?
Must my days be dark by reason, Heavens, of your boundless nights,
Rush of Suns, and roll of systems, fiery clash of meteorites?

"Spirit, nearing yon dark portal, limit of thy human state,
Fear not thou the hidden purpose of that Power, the one, the great,
Nor the myriad world, His shadow, silent Opener of the Gate."

Has not the sense of inharmony disappeared? What, then, was its cause? In (41*a*) the verses are full Romance verses of eight units; in (41), on the other hand, each verse contains *nine* units, the first half of the verse four, the second half five. The intruding ninth unit was the cause of the inharmony; it was as though one, thinking to have reached the stair-foot, had found another step. As Browning's verse in (35*h*) was an unbalanced Ballad verse, so Tennyson's is an unbalanced Romance verse—a solitary example.

21. To summarize this section, the "verse-unit" of British lyric measures, which are all included in Romance metre and its three variants, is a verse of eight stress-units or their equivalent; as—

Romance.

Ye banks and braes o' bonie Doon, how can ye bloom sae fresh and fair ?

Ballad.

There blew a drowsy, drowsy wind, deep sleep upon me fell,

Nibelungen.

From Greenland's icy mountains, and India's coral strand,

Alexandrine.

What love of thine own kind ? What ignorance of pain ?

and the dubious

Unpaused Alexandrine.

In profuse strains of unpremeditated art.

To show their connection and variation, these may be divided,—

Ye banks/ and braes/ o' bo/nie Doon/, how can/ ye bloom/ sae fresh/ and fair ?/
There blew/ a drow/sy, drow/sy wind/, deep sleep/ upon/ me fell/, /
From Green/land's i/cy moun/tains, / and In/dia's co/ral strand/, /
What love/ of thine/ own kind ?/ / What ig/norance/ of pain ?/ /
In pro/fuse strains/ of un/preme/dita/ted art/ / (?) /

The last is so irregular that it almost seems to repudiate kinship with the others; nevertheless, as its development from the Alexandrine can be traced, its existence must be recognized. The above examples are all pure duple; the triple metres follow precisely the same laws, so it will be sufficient merely to quote a verse of each variation :—

The glad/ birds are sing/ing, the flow/rets are spring/ing, o'er mea/dow and moun/tain and down/ in the vale/;
The cup/ was all fill'd/, and the leaves/ were all wet/, and it seem'd/, to a fan/ciful view/, /
We sat/ down and wept/ by the wa/ters / of Ba/bel and thought/ of the day/ /
Ah sun/flower ! wea/ry of time/, / who coun/test the steps/of the sun/; /
Consi/der it well/ : each tone/ of our scale/ in itself/ is nought/; / (?) /

Then, again, there is the not yet etheralized quadruple metre, of which the following are examples of Romance and Ballad :—

And the bush/ hath friends to meet/ him, and their kind/ly voices greet/ him in the mur/mur of the bree/zes and the ri/ver on its bars/,
There was move/ment at the sta/tion, for the word/ had passed around/ that the colt/ from old Regret/ had got away/, /

These three—duple, triple, and quadruple—are the extremes of type of the Romance verse and its developments; and over this verse of eight units, each unit with its triple variation of sound and its fourth variation of pause—over this octave of verse—the poets of Britain's Helicon have breathed their hearts into the immortality of song.

Section II.

1. The poems heretofore considered have been those whose stanzas contain an exact number of full verse-units—that is, every verse in the stanza is complete of its kind — Romance, Ballad, Nibelungen, or Alexandrine. There is, however, another form of stanza which, whilst not nearly so common as the perfect form, is yet sufficiently common to demand consideration when deciding upon the "verse-unit." It is a "fixed variation," and any variation that can become fixed must have a large amount of inherent vitality—must be closely akin to the parent form.

2. The "telescoping" of a Romance and Ballad verse has been referred to in paragraph 8 of Section I. It gives rise to a very popular form of stanza :—

(1.) This mayden in a morne betime
Went forth, when May was in her prime,
To get sweet cetywall,
The honeysuckle, the harlocke,
The lilly and the lady-smocke,
To deck her summer hall.

(*Drayton*, "Dowsabel," stanza 6.)

Stanzas such as this would almost suggest that a four-stressed rather than an eight-stressed verse should be adopted as the natural verse-unit. Such a unit would apply to all eight-stressed verses, whilst it would also apply to a large number of others that must otherwise be regarded as exceptions to the law, and variations of the type ; practically the whole of our Lyric measures would conform to the four-stressed unit. Much of the Romance poetry, moreover, is found in four-stressed riming lines, each full Romance verse thus forming a rimed couplet, as in Scott's "Metrical Romances" :—

(2.) Fitz-James look round—yet scarce believed
The witness that his sight received ;
Such apparition well might seem
Delusion of a dreadful dream.
Sir Roderick in suspense he eyed,
And to his look the Chief replied,
"Fear nought—nay, that I need not say—
But doubt not aught from mine array."

("The Lady of the Lake," canto v, secn. xi.)

The very punctuation here indicates that each couplet in the above is a practically complete sentence which it would be a violation to divide with a breath. The verse is divided into two equal parts, but is knit or coupled by the rime. That the couplet is a complete whole is, I think, felt instinctively, and very few readers, if any, would take a breath after every line. It is not denied that advantage may be and is taken of a break such as that after the line

"Fear nought—nay, that I need not say—

but admitting this is only admitting occasional exceptions that do not vitiate the contention that the full Romance verse is the *average* length of a breath-sentence. The very fact that it is an average implies that there were, and may still be, verses longer or shorter. Every law of classification has its exceptions, but when these exceptions are so small a minority in comparison with the conforming numbers they in no way weaken the law.

3. Scott's reasons for adopting the "Romantic stanza," as he calls it, are set out in his introduction to the 1830 edition of "The Lay of the Last Minstrel." He rejected the Ballad measure because "The Ballad measure itself, which was once listened to as to an enchanting melody, had become hackneyed and sickening, from its being the accompaniment of every grinding hand-organ ; and, besides, a long work in quatrains, whether those of the common ballad, or such as are termed elegiac, has an effect upon the mind like that of the bed of Procrustes upon the human body ; for, as it must be both awkward and difficult to carry on a long sentence from one stanza to another, it follows, that the meaning of each period must be comprehended within four lines, and equally so that it must be extended so as to fill that space. . . . In the dilemma occasioned by this objection the idea occurred to the Author of using the measured short line, which forms the

structure of so much minstrel poetry, that it may properly be termed the Romantic stanza by way of distinction; and which appears so natural to our language, that the very best of our poets have not been able to protract it into the verse properly called Heroic without the use of epithets which are, to say the least, unnecessary." In a note to this remark he adds, "Thus it has been often remarked, that, in the opening couplets of Pope's translation of the Iliad, there are two syllables forming a superfluous word in each line, as may be observed by attending to such words as are printed in italics :—

> (3.) Achilles' wrath to Greece the *direful* spring
> Of woes unnumber'd, *heavenly* goddess, sing;
> That wrath which sent to Pluto's *gloomy* reign
> The souls of *mighty* chiefs in battle slain,
> Whose bones, unburied on the *desert* shore,
> Devouring dogs and *hungry* vultures tore."

Scott rebels against the expansion or limitation of thought to the average of four lines—he should have said two lines. He also objects to the extra unit in Heroic verse; but the Heroic was the stepping-stone to Blank verse, a metre that evolved to accommodate sentences of varying length, as the Romance evolved to accommodate sentences of average length; and as the Romance metre will not tolerate sentences that run on from verse to verse, so the best Blank verse will not tolerate verses that do not run on or overflow. Whilst, however, Scott rebels against the yoke, he bows to it; for his sentences, as in the example quoted from "The Lady of the Lake," are nearly always comprised within two lines—a verse. Whilst, too, he rejects the formal ballad as his vehicle, he constantly admits it to relieve the monotony of the "Romantic stanza" (see in "The Lay of the Last Minstrel," canto i, sections x, xii, xiii, xviii, xxiv, &c.). It will scarcely be denied that Ballad verses of seven stresses are recited in one breath to one verse; and admitting this, it is admitted that the parent verse, the Romance, *was* recited in a breath. Had Scott's tales been sung—as, indeed, they were supposed to be sung in the Lay—Ballad metre would, without doubt, have much more largely predominated. The eye, however, does not require the rests required by the breath; and the period elapsing between the evolution of the Ballad form from the Romance and the time of printing is so comparatively short that, whilst the Ballad had time to become a most vigorous living form, the Romance also was given new life ere it had joined the hexameter and runic stave as a fossil parent form. In the formal ballad that Scott and others condemned, even despised—the ballad whose form appeared to be of greater moment than its thought—the form was, as it were, making root and wood; it throve sturdily and persistently among other and more tended forms, and upon its vigorous stock are now grafted the finest flowering of British lyrics.

4. A reason has already been given for supposing that the Romance verse was shortened by the dropping of a unit to admit of a breath being easily taken (see paragraph 8 of Section I). Were a breath taken after each line of four stresses, as is *usually* done in Church congregations (maugre Section I, paragraph 8), there would have been no need for any shortening at all. The mere fact that there was a tendency to shorten the eight-stressed verse shows that there was a tendency to take the whole in one breath, and it is for this reason that the unit of verse-length has been taken as the breath-sentence, or full verse of eight stresses, rather than as

the half-verse, or line of four stresses. The breath-sentence, as a rule, falls naturally into two parts :—

(4.) Everye white will have its blacke,
  And everye sweete its sowre ;
This founde the ladye Christabelle
  In an untimely howre.

For so it befelle, as syr Cauline
  Was with that ladye faire,
The kinge her father walked forthe
  To take the evenyng aire :

And into the arboure as he went
  To rest his wearye feet,
He founde his daughter and syr Cauline
  There sette in daliaunce sweet.

The kinge hee sterted forthe, I-wys,
  And an angrye man was hee :
'Nowe, traytoure, thou shalt hange or drawe,
  And rewe shall thy ladie.'
("Sir Cauline," part II, stanzas 1 to 4)

If this or any other ballad be read aloud, it will be found that the breath is invariably taken after the seventh stress, at the place of the dropped eighth unit. It may be said that advantage is taken of the verse-end to take the breath, not that the verse was moulded of a length to enable the breath to be so taken ; but the breath is the imperative need, and it is more likely that the articulations borne on the breath will be made coterminous with the natural breath than that the natural breath will be unduly shortened or lengthened to accommodate the articulations. Development is along the lines of least resistance, and it is easier to accommodate the articulations to the breath than the breath to the articulations. Again, it is easier to take a leisured breath than it is to take a hurried breath ; and the unit was dropped from the eight-stressed Romance verse to avoid the gasp and discomfort of a hurried breath. Now, whilst the unit was usually dropped at the verse-*end*, instances may have occurred—indeed, must almost necessarily have occurred—where the unit was dropped at the opening of the second verse, and not at the end of the first. In the fourth stanza of example No. (4) the verse

(5.) The kinge hee sterted forthe, I-wys, and an angrye man was hee,

can be divided either as two lines of four and three stresses respectively :—

(5*a*.) The kinge hee sterted forthe, I-wys,
  And an angrye man was hee :

or as two lines of three and four stresses respectively :—

(5*b*.) The kinge hee sterted forthe,
  I-wys, and an angrye man was hee :

Verses of the latter type are of frequent occurrence, and are probably examples of a type where the unit was dropped at the beginning of the second verse instead of at the end of the first. The following occur in the first book of Chapman's translation of Homer's "Iliad" :—

(6.) *a*. Jove's and Latona's son/ ; who, fired against the king of men (Verse 4.)

b. Obeying his high will/, the priest trod off with haste and fear ; (Verse 33.)

c. And quiver covered round/, his hands did on his shoulders throw ; (Verse 44.)

d. Filled all his faculties/ ; his eyes sparkled like kindling fire, (Verse 101.)

Also verses 134, 163, 202, 210, 239, 242, and 249. It is probable that in poetry, in the transition stage from Romance to Ballad, these heavy-ended verses will be found in more abundance than in later poetry. In natural growths all departures from the "type" tend to die out, seeing that the type is the mean result of many varying forms of which the departures are individuals only. If they have sufficient vigour to persist, they may produce new forms—fixed variations. When poetry was more recited than written the process of elimination of departures from type would be carried on in the speech, and it is only when the departures have become fossilized in manuscript that we can see the process at work. Had Chapman's verses been memorized and recited instead of being written, it is probable—almost certain—that the heavy-ended verses would have been changed; nor would any great change be needed to convert them into the light-ended, heavy-headed verses of the "type"—the Ballad.

(6*a*.) Obeying his high will, the priest trod off with haste and fear

would easily become

(6*b*.) The priest, obeying his high will, trod off with haste and fear;

and so on. Whilst the verses quoted in example No. (6) seem unbalanced when separated from the context, they are, when read in the poem, paused in accordance with rhythmical division, not syntactical:—

(7.) *a*. Jove's and Latona's son; who, fired
Against the king of men

b. Obeying his high will, the priest
Trod off with haste and fear;

c. And quiver covered round, his hands
Did on his shoulders throw;

This reversed division occurs with a new feature in modern poetry:—

(8.) Well does the May that lies
Smiling in thy cheeks, confess
The April in thine eyes;
Mutual sweetness they express.
No April e'er lent kinder showers,
Nor May returned more faithful flowers.
(*Crashaw*, "Saint Mary Magdalene.")

(9.) So it is, my dear.
All such things touch secret strings
For heavy hearts to bear.
So it is, my dear.
(*D. G. Rossetti*, "Even So.")

(10.) Go forth! for she is gone!
With the golden light of her wavy hair,
She is gone to the fields of the viewless air,
She hath left her dwelling lone!
(*Mrs. Hemans*, "The Bird's Release.")

(11.) A voice from Scio's isle—
A voice of song, a voice of old
Swept far as cloud on billow rolled,
And earth was hushed the while.
(*Mrs. Hemans*, "The Voice of Scio.")

The new feature is the place now taken by the pause; it neither precede nor follows the Ballad verse, but divides it, so that the first line in each example is, as it were, isolated, the latter half of the first full verse com-

bining with the next verse. Take example No. (11), in which are combined two full Ballad verses. As read, this stanza is divided by the pause :—

(11*a*.) A voice/ from Sci/o's isle/— / a voice/ of song/, a voice/ of old/
Swept far/ as cloud/ on bil/low rolled/, and earth/ was hushed/ the while/.

The first three stresses are isolated, and the rest of the stanza is knit into a perfect whole. The heavy half of the Ballad verse refuses to follow—it will lead, as does the heavy head of the arrow—and a new combination results. Let two stanzas be quoted :—

(11*b*.) A voice from Scio's isle—
A voice of song, a voice of old
Swept far as cloud on billow rolled,
And earth was hushed the while.

The souls of nations woke !
Where lies the land, whose hills among
That voice of victory hath not rung
As if a trumpet spoke ?

In both stanzas, and in every stanza of the poem. the first line of three accents is separated from the rest of the stanza by a pause ; the rime is its sole connection, from a metrical point of view. Omit the first line of the two stanzas quoted :-

(11*c*.) A voice of song, a voice of old
Swept far as cloud on billow rolled,
And earth was hushed the while.
Where lies the land, whose hills among
The voice of victory hath not rung
As if a trumpet spoke ?*

Substitute for "And earth was hushed the while," "Nor earth the silence broke," and the "Dowsabel" stanza is the result. Or if the pause isolating the first line be filled—

(11*d*.) A voice from Scio's isle, 'tis told,
A voice of song, a voice of old
Swept far as cloud on billow rolled,
And earth was hushed the while

The souls of nations woke and sung,
Where lies the land, whose hills among
That voice of victory hath not rung
As if a trumpet spoke ?

—the stanza of "Helen of Kirkconnel" results, this stanza being a combination of a Romance with a Ballad verse, as the former is the "telescoping" of those two verses.

5. Another possible origin may be conjectured. Bishop Percy, in his Reliques, has fortunately preserved an unpolished piece of work from the stithy of the poet's brain. He prints the first stanza of "A, Robyn, Jolly Robyn" :—

(12.) "A, Robyn,
Jolly Robyn,
Tell me how thy leman doeth,
And thou shalt know of myn."

* Reference might be made to the remarks by Professor Saintsbury on what has in this paper been called the Dowsabel form of verse, in "History of English Prosody," vol. i., pp. 92, 93.

And the second stanza :—

"My lady is unkynde perde."
"Alack! why is she so?"
"She loveth an other better than me;
And yet she will say no."

The Bishop remarks, "Yet the first stanza appears to be defective, and it should seem that a line is wanting, unless the first four words were lengthened in the time." But the two fragmentary lines—

A, Robyn,
Jolly Robyn,

—simply form half of a Romance verse; and the stanza runs trippingly as—

(12*a*.) "A, Robyn, jolly Robyn,
Tell me how thy leman doeth,
And thou shalt know of myn."

—which, again, forms half of a "Dowsabel" stanza. These fragmentary lines give body to a certain thought that lies at the back of the mind when it is said that the Romance verse is the *average* length of a spoken or recited sentence—the thought that in old ballads, newly taking shape, there must have been many sentences that either exceeded or fell short of the average. These erratic verses would naturally be altered to conform to type, or if they proved inconformable they would be replaced by others, and would in either case disappear. If, indeed, they were possessed of sufficient vitality, and were on the lines of natural development, they would become established as permanent variations, or might even supplant the parent type, becoming themselves the new type from which subsequent variations would flow. The latter is the case with the Ballad metre, which threatened to supplant the Romance metre; the former is the case as regards the permanent variations of the Alexandrine and Nibelungen metres. This constant alteration and development was a process at first largely carried on in the minds of the singers or reciters: a verse that sounded harsh when recited by one poet would be altered by another with perhaps a finer ear, and so the change would go on until the whole poem was conformable to type, or until it had been caught and set up by a scribe, becoming an example for all time. Even after a poem had been committed to manuscript, and often during that very process, it underwent new changes, until, excepting for the matter, the two forms can hardly be recognized as being originally one and the same.

6. A short study of the "Ancient Ballad of Chevy Chase" will reveal the existence of many varieties of verses, some of which are now fixed types, but most of which are obsolete. One stanza is printed by Bishop Percy :—

(13.) "Nay [then]" sayd the lord Persè,
"I tolde it the biforne,
That I wolde never yeldyde be
To no man of woman born."
(Part ii, stanza 11.)

The "then" of the first line was inserted by Percy, so that in the manuscript the stanza had a very different opening :—

(13*a*.) "Nay" sayd the lord Persè,
"I tolde it the biforne,

Divided, the two forms side by side are,—

(13*b*.) "Nay/ then" sayd/ the lord/ Persè/, "I tolde/ it the/ biforne/,
"Nay" sayd/ the lord/ Persè/, / "I tolde/ it the/ biforne/,
[or] "Nay"/ sayd the lord/ Persè/, / "I tolde/ it the/ biforne/,

Similarly, the stanza given by Percy as opening—

> (14.) The[y] tooke [on] on ethar hand
> Be the lyght off the mone ;
> (Part ii, stanza 25)

—should be,—

> (14*a*.) The tooke on ethar hand
> Be the lyght off the mone ;

Again comparing the divided forms :—

> (14*b*.) The[y]/ tooke [on]/ on e/thar hand/ be the lyght off/ the mone/ ;
> The tooke/ on e/thar hand/ / be the/ lyght off/ the mone/ ;

In both instances Percy has made an abrupt Ballad verse out of what was originally an ordinary Alexandrine. Such alternation of Alexandrine with Ballad was and is common enough: an example by the Earl of Surrey has been given in example No. (28), Section I, of this chapter. The Nibelungen verse is also found in "Chevy Chase"—

> (15.) Then sayd the doughtè Doglas
> Unto the lord Persè :
> "To kyll all thes giltless men,
> A-las ! it wear great pittè.
> (Part i, stanza 19)

> (15*a*.) Then sayd/ the dough/te Dog/las / unto/ the lord/ Persè/ :

—though by the accent-marks Percy would make the verse Alexandrine. In the stanzas following hereunder the Ballad of the first verse dwindles to Nibelungen in the second and third, and to Alexandrine in the fourth :—

> (16.) Thear was slayne with the lord Persè
> Sir John of Agerstone,
> Sir Roger the hinde Hartly,
> Sir Wyllyam the bolde Hearone.
>
> Sir Jorg the worthè Lovele
> A knyght of great renowen,
> Sir Raff the ryche Rugbè
> With dyntes were beaten downe.
> (Part ii, stanzas 28, 29)

> (16*a*.) Thear/ was slayne/ with the lord/ Persè/ Sir John/ of A/gerstone/,
> Sir Ro/ger the hin/de Hart/ly, / Sir Wyl/lyam the bolde/ Hearone/.
> Sir Jorg/ the wor/thè Lo/vele / a knyght/ of great/ renowen/,
> Sir Raff/ the ryche/ Rugbè/ / with dyn/tes were bea/ten downe/.

The swelling of the Ballad to the parent Romance is even more noticeable :—

> (17.) The dougheti Dogglas on a stede
> He rode att his men beforne ;
> His armor glytteryde as dyd a glede ;
> A bolder barne was never born.
> (Part i, stanza 14.)

> (17*a*.) The dough/eti Dog/glas on/ a stede/ he rode/ att his men/ beforne/ ; /
> His ar/mor glytt/eryde as dyd/ a glede/ ; a bol/der barne/ was ne/ver born/.

It swells to full Romance in both verses of the following :—

> (18.) Tivydale may carpe off care,
> Northombarlond may mayk grate mone,
> For towe such captayns, as slayne wear thear,
> On the march perti shall never be none.
> (Part ii, stanza 34.)

> (18*a*.) Ti/vydale/ may carpe/ off care/, Northom/barlond/ may mayk/ grate mone,
> For towe/ such cap/tayns, as slayne/ wear thear/, on the march/ perti/ shall ne/ver be none/.

In several verses even the Romance is exceeded :—

> (19.) "Leave off the brytlyng of the dear," he sayde,
> "And to your bowys look ye tayk good heed ;
> For never sithe ye wear on your mothars borne
> Had ye never so mickle need."
> (Part i, stanza 13.)

This "Battle of Chevy Chase" is a stirring, rugged old Ballad ; and the process of forcing to type is clearly seen when the foregoing stanzas are compared with the parallel stanzas in the later version, given by Percy as "the more improved edition of that fine Heroic ballad." He says the bard of the latter has "everywhere improved the versification"—that is, he has brought it into strict conformity with type. In this "improved edition" quotation No. (13) becomes—

> (20.) "Noe, Douglas," quoth Erl Percy then,
> "Thy proffer I doe scorne ;
> I will not yeelde to any Scott
> That ever yett was borne."
> (Stanza 38.)

Quotation No. (16) becomes—

> (21.) With stout Earle Percy, there was slaine
> Sir John of Egerton,
> Sir Robert Ratcliff, and Sir John,
> Sir James that bold Barron :
>
> And with Sir George and stout Sir James,
> Both knights of good account,
> Good Sir Ralph Raby there was slaine,
> Whose prowesse did surmount.
> (Stanzas 51, 52.)

Here Procrustes has been lengthening the limbs of his victims without a doubt. Quotation No. (17) becomes—

> (22.) Erle Douglas on his milke-white steede,
> Most like a baron bold,
> Rode foremost of his company,
> Whose armour shone like gold.
> (Stanza 17.)

And, lastly, quotation No. (19) becomes the second verse of—

> (23.) All men of pleasant Tivydale,
> Fast by the river Tweede : "
> "O, cease your sports," Erle Percy said,
> "And take your bowes with speede :

All the ruggedness, and much of the life, have disappeared in the course of "improvement," and we may be quite certain that our smoothest ballads have resulted from a similar process. It is possible that even in the older form the process is seen at work in a verse like—

> (24.) That day, that day, that dreadfull day :
> The first Fit here I fynde.
> (Part 1, last stanza.)

—where an Alexandrine—

> (24a.) That day, that dreadfull day :
> The first Fit here I fynde.

—has been swelled to the full Ballad by the insertion of another "that day." Such verses are of very frequent occurrence in the old ballads ; in

"Robin Hood and Guy of Gisborne," a ballad of fifty-nine stanzas as given by Percy, there are five:—

(25.) *a.* "Woe worth, woe worth thee, wicked wood,
That ere thou grew on a tree;
(Verse 35.)

b. Saies, "Lye there, lye there, now sir Guye,
And with me be not wrothe;
(Verse 87.)

c. "Hearken, hearken," sayd the sheriffe,
"I heare now tydings good,
(Verse 95.)

They are also of frequent occurrence in modern ballads, as in Coleridge's "Rime of the Ancient Mariner":—

(26.) *a.* Water, water, everywhere,
And all the boards did shrink;
Water, water, everywhere
Nor any drop to drink.

b. "Fear not, fear not, thou wedding-guest!
This body dropt not down.

And many others. In many instances the repetition adds force,* but in as many it appears to be mere filling-out to obtain conformity to type.

7. An amplification of a somewhat different kind appears in Burns's poem:—

(27.) O, wert thou in the cauld blast
On yonder lea, on yonder lea,
My plaidie to the angry airt,
I'd shelter thee, I'd shelter thee.
Or did Misfortune's bitter storms
Around thee blaw, around thee blaw,
Thy bield should be my bosom,
To share it a', to share it a'.

Every verse of both stanzas of the poem echoes in the same way. An abruptness, otherwise too apparent, is rounded off by the echo. There is no echo in Walsh's "Mo Craoibhin Cno," and the result is almost disagreeable:—

(28.) The high-bred dames of Dublin town
Are rich and fair,
With wavy plumes and silken gown,
And stately air;
Can plumes compare thy dark-brown hair?
Can silks thy neck of snow?
Or measured pace thine artless grace,
Mo craoibhin cno,
When harebells scarcely show thy trace,
Mo craoibhin cno?
(Stanza 2.)

Again, one is inclined to draw out the "rich and fair" like "love's young dream" in the example with No. (28*b*) of Section I, or to echo as in Burns's stanza, the reason being that the verse as it stands—

(28*a*.) The high-bred dames of Dublin town
Are rich and fair,

---

* As in Coleridge's
Alone, alone, all, all alone,
Alone on a wide, wide sea!

—is not conformable to type: it is, in reality, an unpaused Alexandrine. The same is true of the two concluding verses of Burns's characteristic "Mouse stanza":—

(29.) Still thou art blest, compared wi' me!
The present only toucheth thee:
But och! I backward cast my e'e
On prospects drear!
An' forward, tho' I canna see,
I guess an' fear!

These remarks properly belong to the chapter on the stanza, being merely touched upon in this place in connection with irregular verse-lengths as affecting the "type."

8. Coming to modern times, we may glance at the treatment of the fine old Danish ballad "Agnes and the Merman." A translation is given of the version appearing in Svend Grundtvig's "Danmarks Folkeviser," published in 1882. As this is intended to illustrate the metre, the broken lilt of the original is as nearly as possible adhered to, and the translation is divided so that the lilt may more readily be perceived. The words that would bear the metrical stress, were the verses made to conform to type, immediately precede the firm bar; words whose stress must then be suppressed, though they would probably have received stress when the poem was recited in olden days, precede the broken bar:—

(30.) 1. Agne/te she stands/ on the High/land bridge/,
Singing the birds are.
And up/ came the Mer/man from bil/low's blue ridge/.
Lovely Agnete!

2. As pu/rest gold-/glimmer so/ was his hair/,
The joy/ of his heart/ in his eyes/ lay bare/.

3. "And hear/ thou, Agne/te so fair/ and so fine!/
And wilt/ thou become/ now the All-dear/est of mine?"/

4. "Oh, yes/ indeed/, that will/ I do/,
If thou ta/kest me un/der the bil/low so blue."/

5. Her ears/ then he/ has clo/sèd, her mouth/ covered o'er/,
Then down/ to the o/cean's deep/ the maid/ he bore/.

6. From o/cean's floor/ his dwel/ling uprose/,
Agne/te in shoes/ of red gold/ therein goes/.

7. There wonned/ they toge/ther for eight/ full years/,
Sons se/ven and a daugh/ter to the Mer/man she bears/.

8. Agne/te she sat/ at cra/dle and sang/:
Then hears/ she in En/gland the clocks/ as they clang/.

9. Agne/te she goes/ before,' the Mer/ man to stand/:
"And may/ I but once/ go to kirk/ on land?"/

10. "Oh, yes/ indeed/, that well/ may fall/,
If thou seek'st/ here again/ thy chil/dren small"/.

11. "Yes, tru/ly and of sure/ty them seek/ will I/:
Therĕ lies naught/ in the wi/dest earth,/ my heart/ so nigh"/.

12. "But when/ thou now/ in the kirk/ shalt go/,
Thou shalt not/ deck thy bo/som with gold's/ ruddy glow/.

13. "And when/ thou stepp'st/ in the kirk-/yard there/,
Then must thou/ not shake free/ thy love/ly gol/den hair/.

14. " And when/ thou trea/dest the house/ of wea pons in/,
Let thy lips/ 'neath thy cra/moisy in no/ smiling twin/.

15. " And when/ thou setts't/ on kirk-floor/ thy feet/,
Must thou not/ turn aside/ to thy mo/ther's dear seat/.

16. " And when named/ by the priest/ is the High/est, /
See thou/ in no bend/ing compli/est." /

17. But now/ when she in/to the kirk/ should go/,
She decked/ herself/ with gold's/ ruddy glow/.

18. And when/ she had stepp'd/ in kirk-/yard there/,
Agne/te shook free/ her love/ly gol/den hair/.

19. And as/ she stepp'd/ the house/ of wea/pons in/,
With smi/ling 'neath cra/moisy her lips/ did she twin/.

20. And when/ she on kirk-/floor set/ her feet/,
Agne/te went in/ to her mo/ther's dear seat/.

21. And when named/ by the priest/ was the Ho/ly, /
Her bo/dy she ben/ded low/ly. /

22. Then whis/pered low/ her mo/ther, who stood/ full near/ :
" Agne/te ! Agne/te ! whence co/mest thou here ?/

23. " Agne/te ! Agne/te ! dear daugh/ter so mild !/
Where/ hast thou tar/ried these years/, my child ?/

24. " Where/ hast thou tar/ried so long/ a time ?/
And why/ is thy cheek/ as the win/ter rime ? "/

25. " My dwel/ling stands/ in o/cean's green growth/,
And there/ have I gi/ven the Mer/man my troth/.

26. " There/ shines no sun/ as here/ so bright/ly,
There/fore my cheeks/ are blan/chèd so white/ly.

27. " Se/ven good sons/ in's arm/ have I laid/,
The eighth/ one dear/ is so tin/y a maid "/.

28. " What gift/ did the Mer/man on thee/ bestow/
When thy/ bride-fes/tal was held/ below ? "/

29. " Me/ he gave/ five cir/clets of gold/,
And therein/ lay both ro/ses and li/lies untold/.

30. " And me/ he gave/ the gol/den red band/,
The queen/ herself/ no bet/ter may bind/ on her hand/.

31. " And me/ he gave/ the gold-/buckled shoe/,
The queen/ herself/ no bet/ter on foot/ ever knew/.

32. " And me/ he gave/ a gold-framèd harp/,
To play/ on if sor/row should sting/ me sharp/.

33. " But now/ will I dwell/ on the green-/growing shore/,
And ne/ver will/ I down/ to the o/cean more "/.

34. They deemed/ them alone/ and that none/ else knew/,
But near/ stood the Mer/man and hear/kened thereto/.

35. The Mer/man he trod/ the kirk-door/-way within/,
All/ the ho/ly i/mages they turned/ themselves/ from him/.

36. As pu/rest gold-/glimmer so/ was his hair/,
His sor/row of heart/ in his eyes/ lay bare/.

37. " Agne/te ! Agne/te ! come to o/cean with me !/
For the small/ things, thy chil/dren, long/ for thee"/.

38. " Yea/, let them long/ for me, while long/ they will !/
They ne/ver again/ my arms/ shall fill "/.

39. " Oh think/ of the stur/dy ! and think/ of the small !/
The dear/ in the cra/dle, think of her/ most of all ! "/

40. " Nay, ne/ver will/ I think/ of them, stur/dy ones or small/,
Of her/ in the cra/dle will I think/ least of all "/.

41. The Mer/man uplif/ted his/ right hand/ :
" Dule/ and dark/ness be on all/ the land ! "/

42. Dark/ness came/ and hea/vy cloud/,
They lay/ on the mead/ and the town/ a shroud/.

43. The dule/ and the dark/ness blind/ her, /
Agne/te no way/ can find/ her. /

44. She pur/posed to have has/ted o/ver green-/growing shore/,
Then took/ she the path/ to o/cean's floor/.

45. She pur/posed to have has/ted to her mo/ther's home/,
Then took/ she the path/ to o/cean's foam/.

46. " O wel/come, Agne/te, to the bil/low's blue day !/
Yet no/ more on/ the green-/growing earth/ shalt thou stray/.

47. " No more/ shalt thou/ e'er stray/ on the green-/growing shore/,
And gaze/ upon/ thy chil/dren, the small/ things ! no more/.

48. " But here/ shalt thou sit/ on the gra/nite's hard stones/,
And here/ mayst thou dal/ly with dead/ men's bones/.

49. " One thing/ to thee/ I spare/, thy harp/ of red gold/,
To mur/mur the grief/ thy heart/ shall hold "/.

50. Men heard/ a sad mur/mur in wood-/land's green ways/ :
Singing the birds are.
Agne/te her harp/ in o/cean plays/.
Lovely Agnete !

This ballad was very widely known and loved. At the time Grundtvig was compiling his collection, in the nineteenth century, it was still sung in all parts of Denmark, in Norway, Sweden, North Germany, and the neighbouring Slavic lands. It often concludes at the 40th stanza, where Agnete refuses to return with the Merman ; when continued, the part from stanza 41 onwards varies considerably in different countries. The 47th stanza has a keen dramatic touch ; an exclamation of pity rises involuntarily to the lips. Beauty and pathos well from these two-lined stanzas, rugged as they are ; and it is evident that here the story is all-in-all—the Procrustean spirit has not yet become sufficiently powerful to fetter the thoughts springing directly from the heart, and uttered with the heart at the lips. But it is with the metrical form that we are at present concerned. The name Agnete has been retained in the translation as more conformable to the metre. The stanzas are the simplest possible—merely one verse of two lines, being the simple single thought broken into its two parts. Yet the " type " has even here so far evolved that the whole of the stanzas at least suggest it. Occasional verses appear absolutely unmetrical, yet in all can be seen the germ of the eight-stressed verse, the Romance. Stanza 5, when falling from the lips of simple singers, would still, probably, be a ten-stressed verse, as indicated by the division into units in the foregoing translation. To obtain conformity to type, the second unit of the first line and the second unit of the second line, contain-

ing respectively four and five syllables, would have to be "reduced" by the taking-away of a certain number of syllables. This process would be so simple that it is quite evident that the reciters as yet felt no necessity to reduce either the number of stresses or the number of syllables—that is to say, the "form," whilst it was in course of development, had not begun to obtrude—detrition was going on, but unconsciously. In the verse under consideration its structure is more conformable, as under :—

(30*a*.) He clo/sèd her ears/ and her mouth/ covered o'er/,
Then down/ through the o/cean the maid/ he bore/.

It is not for one moment intended that this were any improvement whatever; it is merely intended to show that the reciters had not yet become self-conscious as regards type. In the fifty verses, or one hundred lines, of which the whole poem is composed, there are thirty-five units of four syllables, and one of five syllables, the most remarkable example being the second line of the 35th stanza :—

(30*b*.) 1. All/ the ho/ly i/mages they turned/ themselves/ from him/.

Given its due stresses, this line becomes a full Ballad verse :—

2. All/ the ho/ly i/mages/ they turned/ themselves/ from him/.

The full stanza might almost be regarded as a very crude embryo of the Dowsabel stanza :—

3. The Mer/man trod/ the door/ within/
But all/ the ho/ly i/mages/
They turned/ themselves/ from him/.

Stanza 26 is alone in being a feminine Romance verse. The verses so far noted are those tending to exceed or actually exceeding the average verse of the type. There are three verses that fall below the average, resolving themselves into feminine Nibelungen: these are contained in stanzas 16, 21, and 43, and their effect is most pleasing and characteristic. As regards the free blending of duple and triple units (the quadruple have already been noted), attention need only be directed to stanzas 4, 10, 26, 28, 29, and 42 as typical instances.

As two utter contrasts in British treatment of this beautiful ballad, attention may be called to Robert Buchanan's quatrains in his "Ballad Stories" published in 1869, and Matthew Arnold's exquisite adaptation, "The Forsaken Merman."

9. As the stanza-form of "Agnes and the Merman" is of the simplest kind, it is possible that the verses were varied as independent members, no connection being felt between any one verse and the one either foregoing or following—that is to say, no *formal* connection. A few examples may therefore be quoted of stanzas that have advanced considerably in their formal development, stanzas that are built up of *two* verses, or four lines, and whose verses show decidedly that the Romance verse had shortened to the Ballad. Again the examples are from an old Danish ballad in Grundtvig's collection—"Svend Svejdal." The stanzas chosen are not all consecutive, their places in the ballad being indicated by the number prefixed before each one :—

(31.) 4. Ne/ver thou/ in sleep/ shalt slum/ber,
Nor e/ver rest/ shalt gain/,
Till thou/ hast loosed/ the sor/rowful-heart/ed,
Who ma/ny days/ in fet/ters has lain/.

8. Stood/ the youth/ful Svej/dal,
He raised/ his voice/ in call/ing :
The walls/ of rock/ were rent/ asun/der,
The moun/tain qui/vered as,/ 'twere fall/ing.

14. If now/ I must/ arouse/ me /
From sleep/ and trance/ abi/ding, /
Thou/ on ways/ full ma/ny /
Soon/ shalt forth/ be ri/ding. /

17. Yet/ shall I give/ thee the ring/ of red gold/,
Upon/ thy hand/ it shall glow/ then :
Once/ thou hast found/ her thy mai/den high-born/,
Thyself/ she shall full/ well know/ then.

28. Li/on and/ the un/tamed bear/
They stood/ and the door/ deten/ded :
And ne/ver li/ving man/ might en/ter therein/,
Sa/ving young Svej/dal him/ befrien/ded.

48. Now has/ the youth/ful Svej/dal /
O'er come/ both fear/ and pain/ that encum/bered,
Nor fet/ter they/ the mai/den high-born/,
Full deep/ at his side/ she slum/ bered.
Good heed of thy speech have !

Most observable is the great variety of the rhythm ; duple and triple units do not meet in antagonism, they blend in harmony. In stanza 4 the Ballad returns to full Romance, unless a unit of four syllables, with a minor mid-stress, be admitted as the second unit of the last line. In stanza 8 a feminine Nibelungen (similar to stanzas 16, 21, and 43 of "Agnes and the Merman") is followed by a feminine Romance. Stanza 14 is composed of two duple feminine Nibelungen verses, and contrasted with these are the verses of stanza 17, which are almost full triple feminine Ballad. In stanza 28 the first half of a Romance verse contains a quadruple unit which would, were its due mid-stress allowed, make a line of five stresses, followed by one of four; in fact, a nine-stressed Romance verse would result. To British ears these heavy verses will sound unnatural, and unmusical, if not harsh ; yet they are of value—apart always from their undoubted natural beauty and delightfulness—as illustrations of types of verse through which our own smoothest (and often too smooth) Ballad poetry has passed. Nor have they yet lost their pristine melody to the folk of the lands wherein they were cradled. Moreover, may we not in our own beloved psalms (unmetrical, save the mark !) find four, five, or more words huddled together about a single stress ? The struggle against conformity to type must ever have been sharp, and it certainly was long-continued ; but wheresoever there was poetry there was, irrespective of the "form," imperishable beauty ; and it is this very immortality of loveliness that has preserved so many of the crude media through which the divine light passed from man to man, from age to age—one might almost say from everlasting to everlasting. The myriad-man caught the cry of the struggle : he spoke of either the Romance or the Ballad when he spoke of the

. . . stretchèd metre of an antique song :

and of a surety he refers to the struggle between the two in the "Midsummer Night's Dream."

Quince. Well, we will have such a prologue ; and it shall be written in eight and six.

Bottom. No, make it two more ; let it be written in eight and eight.

("A Midsummer Night's Dream," III, i.)

Two lines of eight and six (syllables) is Ballad ; eight and eight, Romance.

10. To return again to the Dowsabel stanza, it is probable that its full development cannot be traced in British poetry; it possibly began its evolution in France—Warton derives it from the French chansons.* Its source may lie in the same fount from whence flowed the Latin hymns of Adam of St. Victor and others, having reference to hymns of similar substructure. The following is from one by Adam of St. Victor:—

(32.) Verbi vero substantivi,
Caro cum sit in declivi
Temporis angustiâ,
In aeternis verbum annis
Permanere nos Johannis
Docet theologia.

This stanza has been translated by Dr. Neale (incorrectly according to Archbishop Trench†) as follows:—

(32*a*.) That substantive word, united
To the flesh, and therein plighted
To a life of misery sore,
Him to be the Coeternal,
John's theology supernal
Testifieth evermore.

These hymns swell into yet fuller stanzas: The following, again, is by Adam of St. Victor:—

(33.) Jucundare, plebs fidelis,
Cujus Pater est in coelis,
Recolens Ezechielis
Prophetae praeconia:
Est Joannes testis ipsi,
Dicens in Apocalypsi,
Vere vidi, vere scripsi
Vera testimonia.

In this stanza the insertion of a half-verse in each section has converted the irregular Dowsabel stanza into one perfectly regular. Whilst the language of these hymns may be no more than dog-Latin, they have a sonorous, majestic sweep of rhythm. The metre of Poe's "Raven" is based on No. (33). Without authentic specimens of its early forms, it is perhaps unprofitable to speculate as to the actual origin of the combination that results in the irregular Dowsabel stanza. The change from the abrupt (trochaic) form of the Latin hymns to the ordinary duple (iambic) of British verse is due to the syntactic construction of the language, but the actual form of the stanza is the result of metrical forces. It is hardly possible that it was derived from the hymns themselves, as they, when occurring in the form of No. (34), are composed of four-stressed lines throughout—as though in each half of the stanza two *Romance* verses had been "telescoped," not a Romance and a Ballad verse as in the Dowsabel stanza.

11. In paragraph 5 of this section reference was made to thoughts which exceeded or fell short of the average verse. In Ballad metre the verses may lengthen regularly to Romance, or contract to Nibelungen or Alexandrine. In the old Danish ballads examples have been given of verses lengthening even beyond the Romance; but in only one example, No. (30*b*), 1 to 3, was there even an embryonic indication of an apparent

* Warton's "History of English Poetry," as before, p. 29.
† "Sacred Latin Poetry," p. 71.

irregularity that has developed to a regular type. It is conceivable that a Ballad or Romance verse might need considerable extension, yet not so as to equal two verses, to be able to express certain thoughts, and it is also conceivable that during a certain period of the evolution of metre the verse would be lengthened to suit the thought rather than the thought cramped to suit the verse. There are many examples among those given that show this conception to be reasonable. The British ballad of "Sir Cauline" gives examples of "regular irregularities":—

> (34.) Faire Christabelle, that ladye bright,
> Was had forthe of the towre;
> But ever she droopeth in her mynde,
> As nipt by an ungentle winde
> Doth some faire lillye flowre.
>
> (Part ii, stanza 9.)

The thought expressed in the last three lines of the stanza is one of considerable beauty, and it can well be imagined that poet and hearer alike would rather suffer violation of the form than loss of the thought. As regards the metrical construction, one of two things may have taken place: a half-verse of four stresses may have been added, or a half-verse of three stresses may have been dropped. There is, of course, another possible origin, but of so ancient date as to be undiscoverable in British poetry. The vital question is, will the *three* lines be spoken in a breath? The two first certainly are: what difference will be made by the presence of the interloper? Reading aloud having fallen into disfavour, opinion will vary; some will hold that a breath will be taken after "mynde," of the third line, as well as after "towre," of the second. Refer back, however, to the verses quoted in No. (2) of this section, part of "The Lady of the Lake." Will it be denied that in almost every instance in this quotation *two* lines are taken in a breath, and easily taken? It is quite possible to take all three lines of the second part of the stanza from "Sir Cauline" in one breath; with many it is quite an easy matter to do so; and if easy now it would presumably be much more easy at a time when the recitation of verse was the rule, and reading the exception. Be it noted, moreover, that whilst this exceptional construction has, like all other vigorous variations, been taken and made an actual type in some instances, as a rule the construction occurs as an occasional, not as a constant, variation in Ballad poetry; occurring occasionally only, the breath can quite easily make the extra effort required to give utterance to the extra length of verse. A curious instance of the length to which this construction will be carried out *on paper* occurs in Burns's "Battle of Sherramuir":—

> (35.) But had ye seen the philibegs
> And skyrin tartan trews, man,
> When in the teeth they daur'd our Whigs
> And covenant trueblues, man!
> In lines extended lang and large,
> When baig'nets o'erpower'd the targe,
> And thousands hasten'd to the charge,
> Wi' Highland wrath they frae the sheath
> Drew blades of death, till out of breath
> They fled like frighted dows, man!

The reader, too, is out of breath after reading this amazing stanza. The first four lines (two verses) are easily taken in two breaths; then, inveigled by the rimes, the reader is induced to attempt the remainder of the stanza,

six "lines extended lang and large," in two breaths also. In "Sir Cauline" the stanza preceding the one quoted, No. (34), is differently constructed:—

(36.) All woe-begone was that gentil knight
  To part from his ladyè;
And many a time he sighed sore
  And cast a wistful eye:
"Faire Christabelle, from thee to parte
  Farre lever had I dye."

Here a full verse takes the place of the half-verse of four stresses. The stanzas can, of course, easily be made similar:—

(36*a*.) All woe-begone was that gentil knight
  To part from his ladyè;
He sighed sore with many a smart,
"Faire Christabelle, from thee to parte
  Farre lever had I dye."

Seeing that the three-versed stanza required three breaths, it may be contended that, though half of one verse has been dropped, the residue of that verse should still retain its breath, and that the shortened stanza should receive the three breaths. As pointed out in Scott's couplets, however, two riming lines are taken in a breath; moreover, stanzas such as the above were often printed in this way:—

(37.) This mayden in a morne betime
Went forth, when May was in her prime, } To get sweet cetywall,

The honeysuckle, the harlocke,
The lilly and the lady-smocke, } To deck her summer hall.

And so also—

(38.) Alone walking
In thought plaining } all desolate,
And sore sighing

Me remembering
Of my living, } both early and late.
My death wishing

(*Chaucer*, "Virelai.")

The brackets now absolutely couple all that is taken in a breath. If it be held that two breaths are required, where are the verses to be broken? If the couplets be broken, the rule observed in Scott does not hold here; if the couplets be taken together, the short line is absurdly isolated; but if each group be taken in a breath, a smooth, agreeable stanza results. The same holds with the triplets of No. (38). The reader should perhaps be reminded that the question at issue is not how poetry should be read aloud, but what constitutes the verse-unit. And the verse-unit is practically synonymous with the breath-unit, the average length of verse read on one breath.

12. The half-Dowsabel stanza quoted from "Sir Cauline" may be still further extended by the addition of an extra unit to the first, third, and fourth lines:—

(39.) To-night this sunset spreads two golden wings
  Cleaving the western sky;
Winged too with wind it is and winnowings
Of birds; as if the day's last hour in rings
  Of strenuous flight must die.

(*D. G. Rossetti*, "Sunset Wings.")

A complete change of metre has, however, taken place. Lines containing five stresses are blended with lines of three stresses (or four stress-units);

two different types are brought together. The extreme rarity of this blending is sufficient indication that the two are practically different species. and the blending is therefore unnatural. The five-stressed lines are Heroic, and the Heroic is foreign to the Ballad (see Section IV of this chapter). A quite different result is brought about if a unit be dropped from the five-stressed lines of Rossetti's stanza :—

(39*a*.) This sunset spreads two golden wings
  Cleaving the western sky ;
Winged too with wind and winnowings
Of birds ; as if the day in rings
  Of strenuous flight must die.

The metre is sensibly altered ; it has been metamorphosed to the singing Ballad, or Lyric, from the declamatory Heroic.

Section III.

1. It is now desirable to show how the " verse-unit " may be taken as a guide for the classification of British poetry. The " type " is a verse of eight stress-units, or their temporal equivalents. The usual forms of the verse-unit assumed by the type are four :—

1. ROMANCE :	A verse of eight stresses, duple, triple, or quadruple					
2. BALLAD :	,,	seven	,,	,,	,,	,,
3. NIBELUNGEN :	,,	six	,,	,,	,,	,,
4. ALEXANDRINE :	,,	six	,,	,,	,,	,,

Divided, the verse-units are as follow (ordinary duple—or iambic—only being set out) :—

1. ROMANCE :	../../../../../../../../
2. BALLAD :	../../../../../../../ /
3. NIBELUNGEN :	../../../. /../../../ /
4. ALEXANDRINE :	../../../ /../../../ /

In verse-units 2, 3, and 4 the final stress-unit is a blank as regards articulation ; it is used for taking the breath. The *temporal* length of all four verse-units is, therefore, comparatively equal, the inequality being caused through the inability of an inaudible pause to assert itself. In the Romance verse it was necessary to take the breath after the fourth stress-unit and before the first of the following verse ; the result was a slight natural pause, and this pause still makes its presence felt at all verse-endings.

2. In each of the four verse-units certain regular, as well as certain irregular, variations occur. The irregular variations consist of expansions of duple stress-units to triple, or contractions of triple stress-units to duple, and the arbitrary mingling of both. Examples have been given from old Danish ballads in Section II of this chapter, paragraphs 8 and 9. Two stanzas of Shelley's " Sensitive Plant " may be given here :—

(1.) A sen/sitive plant/ in a gar/den grew/,
And the young/ winds fed/ it with sil/ver dew/,
And it o/pened its fan-/like leaves/ to the light/,
And closed/ them beneath/ the kis/ses of night/.

And the Spring/ arose/ on the gar/den fair/,
Like the Spi/rit of Love/ felt e/verywhere/ ;
And each flo/wer and herb/ on Earth's/ dark breast/
Rose/ from the dreams/ of its win/try rest/.

(Part 1, stanzas 1- 2.)

The blending is best heard by the ear when the words are given; it is best seen by the eye when the syllables are represented by dots, as follows:—

(1*a*.)	../.../.../ ../	2, 3, 3, 2 syllables
	.../ ../.../ ../	3, 2, 3, 2 ,,
	.../.../ ../.../	3, 3, 2, 3 ,,
	./.../ ../.../	2, 3, 2, 3 ,,
	.../ ../.../ ../	3, 2, 3, 2 syllables.
	.../.../ ../ ../	3, 3, 2, 2 ,,
	.../.../ ../ ../	3, 3, 2, 2 ,,
	./.../.../ ../	1, 3, 3, 2 ,,

These irregularities are too uncertain to be taken as any index to varieties. The alteration of duple and triple units follows no perceptible rule, but is altogether dependent upon the individual inclination of the writer. The regular variations occur at the opening of the verse and at the two chief "pause-divisions." They occur with most perceptible and definite frequency in the rhythmic breath-pause following the verse-end, and with less frequency and less definiteness at the mid-verse, or *line*-end. Variation at these two points is also dependent upon the inclination of the writer, in so far as he is at liberty to employ them or not as he pleases; but should his first verse show a certain end-variation, the metrical balance almost demands that the same variation shall be present in the following verse, and is more satisfied if the variation is repeated in every verse in the stanza. For instance, when Byron wrote—

(2.) The serpent of the field, by art
 And spells is won from harming;
But that which coils around the heart,
 Oh! who hath power of charming?
It will not list to wisdom's lore,
 Nor music's voice can lure it,
But there it stings for evermore
 The soul that must endure it.

("All is Vanity, saith the Preacher," stanza 3)

—he introduced a variation in the first verse by adding to it a syllable, such syllable falling within the breath-pause, and constituting a "feminine" ending. Having done this, he was obliged to employ the same variation in the second verse; and, whilst metre did not *demand* it, his rhythmic sense led him to employ it in the third and fourth verses also. The same verses are repeated without the repetition of the variation in succeeding verses:—

(2*a*.) The serpent of the field, by art and spells is won from harming;
But that which coils around the heart, oh! who hath power to charm?
It will not list to wisdom's lore, nor music's voice can lure it;
But there it stings for evermore the soul that must endure.

The break is at once perceived, and the ear demands the restoration of full harmony by the repetition of the variation. The variation at the mid-verse, or line-end, is seen in Landor's

(3.) Graceful Acacia! slender, brittle,
 I think I know the like of thee;
But thou art tall and she is little—
 What God shall call her his own tree?
Some God must be the last to change her;
 From him alone she will not flee;
O may he fix to earth the ranger,
 And may he lend her shade to me!

(No. xi of "The Last Fruit off an Old Tree")

He has added a syllable to the first line, such syllable falling in the mid-pause of the verse; but the hearer is not conscious of the same demand for the repetition of this variation, and the stanza could as well have run,—

(3*a*.) Graceful Acacia! slender, brittle, I think I know the like of thee;
But thou art tall, and she is small—what God shall call her his own tree?
Some God must be the last to change her; from him alone she will not flee;
O may he fix to earth the maid, and may he lend her shade to me!

Nevertheless, the fact that the poet repeats the variation is sufficient indication that there is a degree of expectancy; and, if repeated, this first repetition creates a demand for the second. When present at the beginning of the verse the variation consists of the dropping or adding of syllables in the first unit. If the metre be ordinary duple, the natural metre, the dropping of one syllable makes it "abrupt" (trochaic), and it is usual, though by no means obligatory, to continue it as abrupt. If the metre be triple, the dropping of two syllables makes it abrupt (dactylic), whilst the dropping of only one syllable simply gives it an ordinary duple opening; and this is the common opening of triple measures. There is not quite the same demand for regularity in the opening of a verse as in its close, for which fact the rime is responsible; in the example from Shelley's "Sensitive Plant," No. (1) of this section, the verses open either in duple or in triple units, and the poem contains many verses with abrupt opening. If a poem be regularly duple or triple, however, it usually continues as it begins; if it opens ordinarily, it will be ordinary throughout; if abruptly, it will be abrupt throughout.

3. These three regular variations, then, are taken as the index of "varieties" in poems. The verse-end variation, as the most important, distinguishes the varieties; the beginning-variation and the mid-variation distinguish subvarieties. The duple unit being taken as the natural type of unit, the natural Romance verse will be a duple verse of eight stress-units:—

../ ../ ../ ../ ../ ../ ../ ../

This, expanding in all units, may become full triple:—

.../.../.../.../.../.../.../.../

Here each dot represents a syllable; the bars divide the verse into its constituent stress-units, every syllable preceding a bar bearing a stress. It will be remembered that whilst the stress-units may be unequal syllabically, they are equal temporally. The natural Romance verse may expand to the full triple by three different intermediate stages:—

(1.)	../ ../ ../ ../ ../ ../ ../ ../	(2, 2, 2, 2; 2, 2, 2, 2) (Normal).
(2.)	../.../.../.../ ../.../.../.../	(2, 3, 3, 3; 2, 3, 3, 3)
(3.)	../.../.../.../.../.../.../.../	(2, 3, 3, 3; 3, 3, 3, 3)
(4.)	.../.../.../.../ ../.../.../.../	(3, 3, 3, 3; 2, 3, 3, 3)
(5.)	.../.../.../.../.../.../.../.../	(3, 3, 3, 3; 3, 3, 3, 3)

No. (1) is ordinary duple, every unit containing two syllables, as indicated by the figures on the right; No. (2) is duple in the first unit of both half-verses, triple in the remainder; No. (3) is duple in the first unit only; No. (4) is duple in first unit of the second half-verse only; No. (5) is triple throughout. These variations may appear very slight, but they are regular, and they form the basic verse-unit of entire stanzas, examples of which follow:—

(1.) O they/ rade on/, and far/ther on/, the steed/ gaed swif/ter than/ the wind/;
Until/ they reached/ a de/sert wide/, and li/ving land/ was left/ behind/.

("Thomas the Rhymer," stanza 9.)

(2.) My heart's/ in the High/lands, my heart/ is not here/, my heart's/ in the High/lands a-cha/sing the deer/,
A-cha/sing the wild/ deer and fol/lowing the roe/—my heart's/ in the High/lands where/ver I go !

(*R. Burns* "My Heart's in the Highlands.")

(3.) Twelve years/ have elapsed/ since I last/ took a view/ of my fa/vourite field/, and the bank/ where they grew/;
And now/ in the grass/ behold/ they are laid/, and the tree/ is my seat/ that once/ lent a shade/.

(*W. Cowper*, "The Poplars," stanza 2.)

This stanza is defective in so far that it contains two duple units—the third and the seventh in the second verse. The more usual form of the stanza of this type is the one following:—

I saw/ from the beach/, when the mor/ning was shi/ning, a bark/ o'er the wa/ters move glo/riously on/;
I came/ when the sun/ o'er the beach/ was decli/ning, the bark/ was still there/, but the wa/ters were gone/.

(*T. Moore*, "I saw from the Beach," stanza 1.)

(4.) Like the bright/ lamp that shone/ in Kildare's/ holy fane/, and burned/ through long a/ges of dark/ness and storm/,
Is the heart/ that sor/rows have frowned/ on in vain/, whose spi/rit outlives/ them, unfa/ding and warm/.
(Erin, O Erin ! thus bright through the tears of a long night of bondage thy spirit appears.)

(*T. Moore*, "Erin, O Erin," stanza 1)

The above stanza has one intruding duple unit, the second of the second verse.

(5.) The Assyr/ian came down/ like a wolf/ on the fold/, and his co/horts were gleam/ing in pur/ple and gold/,
And the sheen/ of their spears/ was like stars/ on the sea/, when the blue/ wave rolls night/ly on deep/ Galilee/.

(*Lord Byron*, "The Destruction of Sennacherib," stanza 1)

This stanza takes a slightly different form when the first half-verse is given a feminine ending :—

From the brown/ crest of New/ark its sum/mons exten/ding, our sig/nal is wa/ving in smoke/ and in flame/;
And each for/rester blithe/, from his moun/tain descen/ding, bounds light/ o'er the hea/ther to join/ in the game/.

(*Sir W. Scott*, "The Banner of the House of Buccleuch," stanza 1.)

Besides thus expanding to triple, the duple unit may expand to quadruple, so that between Nos. (3) and (4) the following verse should come—

(3c.) ../..../..../..../..../..../..../..../ (2, 4, 4, 4 ; 4, 4, 4, 4)

—which again may be varied by differences in the fifth unit : this unit may contain, two three, or four syllables—three variations. This verse is, however, of extremely rare occurrence, and whilst it need not, perhaps, be included in the scheme of classification, its position may be indicated. A specimen of the verse may be given :—

(3c.) I bless/ them but I'm sad/ for them—I wish/ I could be glad/ for them, for who/ alas ! can tell/ me the fate/ that shall befall ?/
The flow'/rets of the mor/ning, the green/wood path ador/ning, may be scat/ter'd ere the noon/tide by the wild/ wind's sudden call/;

(*C. Mackay*, "Flowers and Children," fifth line from opening.)

The above has two triple units, the seventh of the first verse and the third of the second verse ; but, indeed, this quadruple type of verse is seldom

perfect. Then, following No. (5) should come the quadruple verse with triple opening :—

(5c.) . . . / . . . . / . . . . / . . . . / . . . . / . . . . / . . . . / . . . . /

This verse, again, may vary at the mid-pause by having two, three, or four syllables, making other three variations. This metre is more frequently met with than (3*a*), yet is comparatively rare, at least in the better class of British poetry. The variations in the quadruple verse may be tabulated :—

(3*a*.)	../..../..../..../ ../..../..../..../	(2, 4, 4, 4 ; 2, 4, 4, 4)
(3*b*.)	../..../..../..../ .../..../..../..../	(2, 4, 4, 4 ; 3, 4, 4, 4)
(3*c*.)	../..../..../..../..../..../..../..../	(2, 4, 4, 4 ; 4, 4, 4, 4)
(5*a*.)	.../..../..../..../ ../..../..../..../	(3, 4, 4, 4 ; 2, 4, 4, 4)
(5*b*.)	.../..../..../..../ .../..../. ../..../	(3, 4, 4, 4 ; 3, 4, 4, 4)
(5*c*.)	.../..../..../..../..../..../..../..../	(3 4, 4, 4 ; 4, 4, 4, 4)

An example of (3*c*) has been given ; the following illustrate other of the variations :—

(3*a*.) And how/ the happy Earth/, growing young/ again in mirth/, has
prank't/ herself in jew/els to do ho/nour to the day/—
Of gold/ and purple bright/, of a/zure and of white/ ; her di/adem
and brace/lets, the mea/dow-flowers of May/.

(*C. Mackay*, "'Tis Merry in the Mead," part of stanza 2.)

This has a triple and a duple unit in the first verse besides the duple unit at the opening, whilst in the second verse it has a triple and two duple units besides the duple unit at the opening. As noted in (3*c*), the type is seldom perfect.

(5*b*.) Every mo/tion of the ves/sel, every dip/ of mast or spar/, is a dance/
and a rejoi/cing, and a pro/mise from afar/ ;
And we love/ the light above/ us, as it tips/ the waves around/, all the
more/ because, ere co/ming, it has beam'd/ on English ground/.

(*C. Mackay*, "Rolling Home," part of stanza 3.)

(5*c*.) And the bush/ hath friends to meet/ him, and their kind/ly voices
greet/ him in the mur/mur of the bree/zes and the ri/ver on
its bars/,
And he sees/ the vision splen/did of the sun/lit plains exten/ded,
and at night/ the wondrous glo/ry of the e/verlasting stars/.

(*A. B. Paterson*, "Clancy of the Overflow," stanza 4.)

There's a cry/ from out the Lone/liness—Oh lis/ten, Honey, lis/ten !
Do you hear/ it, do you fear/ it, you're a-hol/ding of me so ?/
You're a sob/bing in your sleep/, dear, and your la/shes, how they
gli/sten—do you hear/ the Little Voi/ces all a beg/ging me to go ?/

(*R. W. Service*.)

There may be a further variation of the quadruple verse : it may open with a quadruple unit. No example of this has been noted, however. Should it be found, its place will fall naturally after (5*c*).

4. The verses exampled in the foregoing paragraph may vary in yet two more ways at the mid-pause—that is to say, in the fifth unit. This unit may contain either one syllable only, or it may contain one syllable more than the normal number contained by the units of the verse. In the former instance the second half-verse opens abruptly ; in the latter instance the first half-verse has a feminine ending.

(6.)	../ ../ . / ../ ./ ../ ../ ../	(2, 2, 2, 2 ; 1, 2, 2, 2)
(7.)	../.../.../... . .../.../.../	(2, 3, 3, 3 ; 1, 3, 3, 3)
(8.)	.../.../.../... ./.../.../.../	(3, 3, 3, 3 ; 1, 3, 3, 3)
(9.)	../ ../ ../ ../. ../ ../ ../ ../	(2, 2, 2, 2 ; 3, 2, 2, 2)
(10.)	../.../.../.../..../.../.../.../	(2, 3, 3, 3 ; 4, 3, 3, 3)
(11.)	.../.../.../.../..../.../.../.../	(3, 3, 3, 3; 4, 3, 3, 3)

The variations (6), (7), and (8) are of very infrequent occurrence; they occur chiefly in isolated verses, not in complete stanzas. There appears to be a repugnance for an abrupt second half-verse to follow a half-verse with ordinary duple or triple opening. No example of No. (6) has been noted; the following verse shows the structure, but is rendered imperfect by the triple unit :—

(6.) The draw/bridge falls/—they hur/ry out/— clat/ters each plank/ and swin/ging chain/,

(*Scott*, "Cadyow Castle," stanza 11.)

The verse would be conformable were the "each" omitted :—

(6*a*.) The draw/bridge falls/—they hur/ry out/— clat/ters plank/ and swin/ging chain/,

The two following are quoted as examples of (7) :—

(7*a*.) The year's/ at the spring/ and day's/ at the morn/: morn/ing's at seven/; the hill-/side's dew-pearled/;
The lark's/ on the wing/; the snail's/ on the thorn/: God's/ in his heaven/- all's right/ with the world/.

(*R. Browning*, from "Pippa Passes.")

The third and seventh units of both verses are defective in being duple, but that is immaterial: the *type* is presented. The following is nearer type, though further from poetry; it is metrically defective only in the sixth unit :—

(7*b*.) As gay/ as a lark/ and as blythe/ as a bee/, hand/some, gen/erous, sprigh/tly, and young/;

(*Cross*, "By goles, I never will marry")

No. (8) is represented by the following :—

(8.) I have read/ her roman/ces of dame/ and knight/; she/ was my prin/cess, my pride/, my pet/,

(*A. L. Gordon*, "The Romance of Britomart.")

Gordon's poem contains several examples of the metre, but all are defective in admitting two duple units—the fourth and eighth in the examples quoted. The construction shown in (9), (10), and (11) is more frequently met with :—

(9.) When love/ly wo/man stoops/ to fol/ly, and finds/ too late/ that men/ betray/,
What charm/ can soothe/ her me/lancho/ly? What art/ can wash/ her guilt/ away?/

(*O. Goldsmith*, "Stanzas on Woman.")

(10.) How long/ didst thou think/ that his si/lence was slum/ber? When the wind/ waved his gar/ment, how oft/ didst thou start?/
How ma/ny long days/ and long weeks/ didst thou num/ber, ere he fa/ded before/ thee, the friend/ of thy heart?/

(*Sir W. Scott*, "Helvellyn," part stanza 3.)

(11.) Of the mail-/cover'd ba/rons, who prou/dly to bat/tle led their vas/sals from Eu/rope to Pa/lestine's plain/,
The escu/tcheon and shield/, which with e/very blast ra/ttle, are the on/ly sad ves/tiges now/ that remain/.

(*Lord Byron*, "On leaving Newstead Abbey," stanza 2.)

The blending of (10) and (11) is shown in the following, where it is curious to note how the humorous writer changes the metre from duple to triple :—

(11*a*.) "When wo/man," as Gold/smith declares/, "stoops to fol/ly, and finds/ out too late/ that false man/ can betray"/,
She is apt/ to look dis/mal, and grow/ melan-cho/ly, and, in short/, to be an/ything ra/ther than gay/

He goes on/ to remark/ that "to pun'ish her lo'ver, wring his bo/som, and draw/ the tear in/to his eye/,
There is/ but one me/thod" which he/ can disco/ver that's like/ly to ans/wer—that one/ is to "die"!/

(*R. H Barham* (Ingoldsby), "The Black Mousquetaire," canto II.)

The quadruple metre may vary in this way also, but no examples have been encountered; when found, they readily fall into place in the scheme.

5. The whole of the examples given in paragraphs 3 and 4 constitute one group of the varieties into which Romance verse is divided. The group may be summarized and tabulated as follows:—

GROUP A.

Variation 1.

Subvariation	(*a.*)	Ordinary duple	Example (1).
	(*b.*)	Triple, with opening and mid-duple	Example (2).
	(*c.*)	Triple, with opening duple ..	Example (3).
	(*d.*)	Quadruple, with opening and mid-duple	Example (3*a*).
	(*e.*)	Quadruple, with opening duple and mid-triple.	
	(*f.*)	Quadruple, with opening duple.	
	(*g.*)	Triple, with mid-duple ..	Example (4).
	(*h.*)	Ordinary triple	Example (5).
	(*i.*)	Quadruple, with opening triple and mid-duple.	
	(*j.*)	Quadruple, with opening and mid-triple	Example (5*b*).
	(*k.*)	Quadruple, with opening triple	Example (5c).
	(*l.*)	Ordinary quadruple with mid-variants if any found.	

Variation 2. (Mid or fifth unit *abrupt* in all cases.)

Subvariation	(*a.*)	Ordinary duple	Example (6).
	(*b.*)	Triple, with opening duple ..	Example (7).
	(*c.*)	Quadruple, with opening duple.	
	(*d.*)	Ordinary triple	Example (8).
	(*e.*)	Quadruple, with opening triple.	
	(*f.*)	Ordinary quadruple.	

Variation 3. (Mid-feminine—*i.e.*, fourth unit with feminine ending.)

Subvariation	(*a.*)	Ordinary duple	Example (9).
	(*b.*)	Triple, with opening duple ..	Example (10).
	(*c.*)	Quadruple, with opening duple.	
	(*d.*)	Ordinary triple	Example (11).
	(*e.*)	Quadruple, with opening triple.	
	(*f.*)	Ordinary quadruple.	

KEY TO GROUP AND VARIATIONS.

1. Any Romance verse whose first unit is ordinary duple, triple, or quadruple—*i.e.*, two-, three-, or four-syllabled, with stress on the last syllable—and whose last unit is stressed on the last syllable, irrespective of number of syllables from one to four, belongs to Group A.
2. Any such verse whose fifth unit contains two or more syllables, up to the number of syllables in the normal unit of that verse, belongs to variation 1—that is, in duple metre the fifth unit must have no more than two syllables; in triple, no more than three; in quadruple, no more than four; and in no case less than two.
3. Any verse whose fifth unit has only one syllable, and that one stressed, making the second half-verse abrupt, belongs to variation 2.
4. Any verse whose fourth unit has a feminine ending followed by a normal fifth unit belongs to variation 3. In a duple verse the fifth unit will then contain three syllables; in triple, four; and in quadruple, five.

5. A combination of variations 3 (*a*) and 2 (*a*) will result in an ordinary duple verse; of Nos. 3 (*b*) and 2 (*b*), in variation 1 (*b*); of Nos. 3 (*c*) and 2 (*c*), in variation 1 (*g*).
6. There may exist rare examples where the fourth unit of a verse falling within this group may end with a *double*-feminine. Should such verse be found it would be classed as variation 4.

In the examples given illustrating the variations of the above group, *regular* verses have been selected—regular, that is, in so far that a duple verse is composed of duple units, a triple or quadruple verse of triple or quadruple units. In all poetry the *tendency* of the units appears to be towards this regularity. The formal school of Pope and Dryden almost insisted upon the necessity for such regularity, but the fact that poets gifted with keener vision and more facile utterance than Pope or Dryden showed repeatedly that the best poetry could be conveyed in irregular verse is conclusive proof that whilst the *tendency* towards regularity exists the *necessity* does not. A great many readers derive more pleasure from a regular than from an irregular verse, and there are many who for this reason would still impose the syllabic fetters. Coleridge's "Christabel" is largely irregular; still more typically so is Shelley's "Sensitive Plant." When Leigh Hunt, in 1835, first published his "Captain Sword and Captain Pen," he found it necessary to remark in the advertisement, "The measure is regular with an irregular aspect, four accents in a verse, like that of Christabel, or some of the poems of Sir Walter Scott:—

> Càptain Swòrd got up one dày—
> And the flàg full of hònour as thoùgh it could feèl—

He" [the author] "mentions this, not, of course, for readers in general, but for the sake of those daily acceders to the list of the reading public, whose knowledge of books is not yet equal to their love of them." Though this development was regarded by many as new, it was in reality a "reversion." The original constitution of poetry was irregular, purely duple and purely triple verses being the result of a slow development.

6. Take again the opening stanza of "The Sensitive Plant":—

> *A sen*/sitive plant/ in a gar/den grew/,
> And the young/ winds fed/ it with sil/*ver dew*/,
> *And it* o/pened its fan-/like leaves/ to the light/,
> And closed/ them beneath/ the kis/*ses of night*/.

The first verse opens and closes with duple units, and the second verse opens and closes with triple units, as italicized; in all cases the stress is on the last syllable of the unit. These facts accord with the requirements of paragraph 1 of "Key to Group," and therefore the verses belong to that group. Again, the fifth unit of the first verse contains a triple and the fifth unit of the second verse a duple unit; and as neither exceeds the length of units found in other parts of the verses, these accord with the requirements of paragraph 2 of the key, and consequently belong to variation 1 of the group. For the rest, the verses are a blending of subvariations (*a*), (*b*), (*c*), (*g*), and (*h*).

7. GROUP B.—This differs from GROUP A in one unit only, the eighth or last. This unit has a feminine ending, or, in other words, is followed by an extra unstressed and unaccented syllable. The variations and subvariations of both groups are identical, and it will not, therefore, be necessary to quote examples for all the subvariations—one for each main variation will suffice.

Variation 1, Subvariation (*a*) :—

(12.) And is/ she dead ?/—and did/ they dare/ obey/ my fren/zy's jea/lous ra/*ving?*
My wrath/ but doom'd/ my own/ despair/: the sword/ that smote/ her's o'er/ me wa/*ving*.
(*Lord Byron*, "Herod's Lament for Mariamne," stanza 2.)

Variation 2, Subvariation (*a*) :—

(13.) *a*. Awake !/ my love/, the sun's/ bright ray/, hills/ and val/leys now/ ador/*ning*.
(*T. Blake*, "Good Morning," opening.)

b. Oh may/ it prove/ for Scot/land's good !/ bon/nie lad/die, High/land lad/*die*,
But why/ so drench/ our glens/ with blood ?/ bon/nie lad/die, High/land lad/*die*.
(*James Hogg*, "Highland Laddie," last stanza.)

Variation 3, Subvariation (*a*) :—

(14.) Her voice/ did qui/ver as/ we par/*ted*, yet knew/ I not/ that heart/ was bro/*ken*
From whence/ it came/, and I/ depar/*ted* heed/ing not/ the words/ then spo/*ken*.
(*Shelley*, "On Fanny Godwin.")

Example (14) is *prosodically* imperfect in the second half-verse of the second verse, which begins abruptly instead of ordinarily. This metre is, however, very rarely met with.

8. Group C.—This differs from Group B in one unit only, the eighth or last. This unit has a *double*-feminine ending. It is seldom met with except in humorous verse, and even then the perfect form occurs only in occasional verses.

Variation 1, Subvariations (*c*) and (*h*) :—

(15.) And e'en/ as Macbeth/, when devi/sing the death/ of his King/, heard "the ve/ry stones prate/ of his where/*abouts*";
So this shock/ing bad wife/ heard a voice/ all her life/ crying "Mur/der !" resound/ from the cu/shion—or there/*abouts*.
(*R. H. Barham*, "Ingoldsby Legends": "A Lay of St. Gengulphus," stanza 73.)

Variation 3, Subvariation (*b*) :—

(16.) Her li/ttle red eyes/ were deep-set/ in their so/*cket-holes*, her gown-/tail was turn'd/ up, and tuck'd/ through the po/*cket-holes*;
(*R. H. Barham*, "Look at the Clock," secn. 1.)

Variation 4, Subvariation (*c*) :—

(17.) And a ten/derer le/veret Ro/bin had ne/*ver ate*; so, in af/ter times, oft/ he was wont/ to asse/*verate*.
(*R. H. Barham*, "The Witches' Frolic.")

9. These three Groups, A, B, and C, comprise Division I of the Romance metre. Division II has also three groups, with their variations and subvariations exactly as in Division I. The two divisions are distinguished by the *first* unit of the verse. All *ordinary* duple, triple, or quadruple openings belong to Division I; all *abrupt* openings to Division II. The former therefore contains all so-called iambic, anapestic, and amphibrachic measures; the latter all trochaic and dactylic. As in the latter division the first units of the verses contain only one syllable in all instances, this division does not exhibit the same amount of subvariation. One or two examples will suffice.

Division II, Group A, Variation 1, Subvariation (*a*) :—

(18.) Aske/ me why/ I send/ you here/ this sweet/ Infan/ta of/ the yeere ?/
Aske/ me why/ I send/ to you/ this Prim/rose thus/ bepearl'd/ with dew ?/
(*Herrick*, "The Primrose," stanza 1.)

Variation 2, Subvariation (*a*) :—

(19.) He/ that loves/ a ro/sy cheek/, or/ a co/ral lip/ admires/,
Or/ from star-/like eyes/ doth seek/ fu/el to/ maintain/ its fires/ ;
(*Carew*, "He that loves . . .")

Variation 3, Subvariation (*a*) :—

(20.) God/ be with/ thee, glad/some O/*cean !* How glad/ly greet/ I thee/ once more !/
Ships/ and waves/ and cease/less mo/*tion*, and men/ rejoi/cing on/ thy shore/.
(*Coleridge*, "On revisiting the Sea-shore," stanza 1.)

Division II, Group B, Variation 1, Subvariation (*a*) :—

(21.) An/nan Wa/ter's wa/ding deep/, and my/ love An/nie's won/drous bon/*ny ;*
I/ will keep/ my tryst/ to-night/, and win/ the heart/ o' love/ly An/*nie.*
("Annan Water," stanza 1.)

The key to the division, then, is in the first unit: if the unit be ordinary (duple, triple, or quadruple), the verse belongs to DIVISION I; if abrupt, to DIVISION II. The key to the groups is in the last units, and to the variations in the fourth and fifth units, as particularized in paragraph 5.

10. Ballad, Nibelungen, and Alexandrine metres vary in the same way, though not to the same extent, owing to the fact that the two latter are the results of a mid-variation of the Ballad. It may be noted that should a Romance verse *drop* its last syllable (stressed), it is no longer Romance, but Feminine Ballad; should it drop the last syllable (stressed) of the first half-verse, it becomes that peculiar and uncommon verse found as the swell of Nibelungen stanzas, which is regarded as Nibelungen reverting to type (see remarks in example No. (16) *g* in paragraph 10). Should a Ballad verse drop the last syllable (stressed) of the first half-verse, it becomes Nibelungen; and should a Nibelungen verse drop the last syllable (unstressed) of its first half-verse, or should a Ballad verse drop the last *unit* of its first half-verse, an Alexandrine results. Should a Ballad verse drop its last unit, it becomes an unpaused Alexandrine; and this latter verse can drop nothing from its last unit without also dropping itself out of the category of metrical verses, unless, indeed, it may be said to result in a Heroic verse of five stresses.

The full tables of the Lyric metres are therefore as follows :—

DIVISION I. 1. ROMANCE METRE.
GROUP A.
Variation 1.
Subvariation—

(*a.*)	../ ../ ../ ../	../ ../ ../ ../	(2 2 2 2 2 2 2 2)
(*b.*)	../ .../ .../ .../	../ .../ .../ .../	(2 3 3 3 2 3 3 3)
(*c.*)	../ .../ .../ .../	.../ .../ .../ .../	(2 3 3 3 3 3 3 3)
(*d.*)	../..../..../..../	../..../..../..../	(2 4 4 4 2 4 4 4)
(*e.*)	../..../..../..../	.../..../..../..../	(2 4 4 4 3 4 4 4)
(*f.*)	../..../..../..../	..../..../..../..../	(2 4 4 4 4 4 4 4)
(*g.*)	.../ .../ .../ .../	../ .../ .../ .../	(3 3 3 3 2 3 3 3)
(*h.*)	.../ .../ .../ .../	.../ .../ .../ .../	(3 3 3 3 3 3 3 3)
(*i.*)	.../..../..../..../	../..../..../..../	(3 4 4 4 2 4 4 4)
(*j.*)	.../..../..../..../	.../..../..../..../	(3 4 4 4 3 4 4 4)
(*k.*)	.../..../..../..../	..../..../..../..../	(3 4 4 4 4 4 4 4)
(*l.*)	..../..../..../..../	../..../..../..../	(4 4 4 4 2 4 4 4)
(*m.*)	..../..../..../..../	.../..../..../..../	(4 4 4 4 3 4 4 4)
(*n.*)	..../..../..../..../	..../..../..../..../	(4 4 4 4 4 4 4 4)

Variation 2.

Subvariation—

(*a.*)	../ ../ ../ ../	./ ../ ../ ../	(2 2 2 2 1 2 2 2)
(*b.*)	../ .../ .../ .../	./ .../ .../ .../	(2 3 3 3 1 3 3 3)
(*c.*)	../..../..../..../	./..../..../..../	(2 4 4 4 1 4 4 4)
(*d.*)	.../ .../ .../ .../	./ .../ .../ .../	(3 3 3 3 1 3 3 3)
(*e.*)	.../..../..../..../	./..../..../..../	(3 4 4 4 1 4 4 4)
(*f.*)	..../..../..../..../	./..../..../..../	(4 4 4 4 1 4 4 4)

Variation 3.

Subvariation—

(*a.*)	../ ../ ../ ../.	../ ../ ../ ../	(2 2 2 2 3 2 2 2)
(*b.*)	../ .../ .../ .../.	.../ .../ .../ .../	(2 3 3 3 4 3 3 3)
(*c.*)	../..../..../..../.	..../..../..../..../	(2 4 4 4 5 4 4 4)
(*d.*)	.../ .../ .../ .../.	.../ .../ .../ .../	(3 3 3 3 4 3 3 3)
(*e.*)	.../..../..../..../.	..../..../..../..../	(3 4 4 4 5 4 4 4)
(*f.*)	..../..../..../..../.	..../..../..../..../	(4 4 4 4 5 4 4 4)

Variation 4.

Subvariation—

(*a.*)	../ ../ ../ ../..	../ ../ ../ ../	(2 2 2 2 4 2 2 2)
(*b.*)	../ .../ .../ .../..	.../ .../ .../ .../	(2 3 3 3 5 3 3 3)
(*c.*)	../..../..../..../..	..../..../..../..../	(2 4 4 4 6 4 4 4)
(*d.*)	.../ .../ .../ .../..	.../ .../ .../ .../	(3 3 3 3 5 3 3 3)
(*e.*)	.../..../..../..../..	..../..../..../..../	(3 4 4 4 6 4 4 4)
(*f.*)*	..../..../..../..../..	..../..../..../..../	(4 4 4 4 6 4 4 4)

Group B.

This group need not be particularized in all its details, seeing that it is exactly the same as Group A, excepting that the last unit is followed by an unstressed syllable, making a feminine ending.

Variation 1.

Subvariation—

(*a.*)	../ ../ ../ ../ ../ ../ ../ ../.	(2 2 2 2 2 2 2 2 +)
(*b.*)	../.../.../.../../.../.../.../.	(2 3 3 3 2 3 3 3 +)

(And so on through the variations of Group A.)

Group C.

As was the case with Group B, there is no need to particularize this group in all its details, seeing that it is exactly the same as Group A, excepting that the last unit is followed by *two* unstressed syllables, making a double-feminine ending.

Variation 1.

Subvariation—

(*a.*)	../ ../ ../ ../../ ../ ../ ../..	(2 2 2 2 2 2 2 2 + +)
(*b.*)	../.../.../.../../.../.../.../..	(2 3 3 3 2 3 3 3 + +)

(And so on through the variations of Group A.)

Division II.

This division differs from No. 1 in that all verses under it begin *abruptly*, or with a stressed syllable.

---

* Note.—Lest it be supposed that the forms (*d*), (*e*), and (*f*) are impossibilities, the two following, specimens of the first and last, are given:—

And from verge unto verge of the starlit profundity
In a murmur of wings is a sound borne along,
And the sound is the cry of the ages' fecundity,
That is visioned in beauty and voiced in song.

And to the centre of the whirlpool with a swift impetuosity
We were impelled and drawn resistlessly along the rapid flow,
With an accelerated motion and a quadrupled velocity
We were engulphed within the Maelstrom in a headlong plunge below.

Truly these may be the veriest doggerel, but both are *possibilities*, and a classifier must open his ears to admit the pipings of Pan no less than the lyrings of Apollo.

GROUP A.

Variation 1.

Subvariation—

(*a.*)	./ ../ ../ ../	../ ../ ../ ../	(1 2 2 2 2 2 2 2)
(*b.*)	./ .../ .../ .../	../ .../ .../ .../	(1 3 3 3 2 3 3 3)
(*c.*)	./ .../ .../ .../	.../ .../ .../ .../	(1 3 3 3 3 3 3 3)
(*d.*)	./..../..../..../	../..../..../..../	(1 4 4 4 2 4 4 4)
(*e.*)	./..../..../..../	.../..../..../..../	(1 4 4 4 3 4 4 4)
(*f.*)	./..../..../..../	..../..../..../..../	(1 4 4 4 4 4 4 4)

Variation 2.

Subvariation—

(*a.*)	./ ../ ../ ../	./ ../ ../ ../	(1 2 2 2 1 2 2 2)
(*b.*)	./ .../ .../ .../	./ .../ .../ .../	(1 3 3 3 1 3 3 3)
(*c.*)	./..../..../..../	./..../..../..../	(1 4 4 4 1 4 4 4)

Variation 3.

Subvariation—

(*a.*)	./ ../ ../ ../.	../ ../ ../ ../	(1 2 2 2 3 2 2 2)
(*b.*)	./ .../ .../ .../.	.../ .../ .../ .../	(1 3 3 3 4 3 3 3)
(*c.*)	./..../..../..../.	..../..../..../..../	(1 4 4 4 5 4 4 4)

GROUP B and

GROUP C vary in the same manner as these two groups vary in DIVISION I—that is, each verse of GROUP A is followed by a feminine or double-feminine ending.

DIVISION I. 2. BALLAD METRE.

GROUP A.

Variation 1.

Subvariation—

(*a.*)	../ ../ ../ ../	../ ../ ../	/	(2 2 2 2 2 2 2 –)
(*b.*)	../ .../ .../ .../	../ .../ .../	/	(2 3 3 3 2 3 3 –)
(*c.*)	../ .../ .../ .../	.../ .../ .../	/	(2 3 3 3 3 3 3 –)
(*d.*)	../..../..../..../	../..../..../	/	(2 4 4 4 2 4 4 –)
(*e.*)	../..../..../..../	.../..../..../	/	(2 4 4 4 3 4 4 –)
(*f.*)	../..../..../..../	..../..../..../	/	(2 4 4 4 4 4 4 –)
(*g.*)	.../ .../ .../ .../	../ .../ .../	/	(3 3 3 3 2 3 3 –)
(*h.*)	.../ .../ .../ .../	.../ .../ .../	/	(3 3 3 3 3 3 3 –)
(*i.*)	.../..../..../..../	../..../..../	/	(3 4 4 4 2 4 4 –)
(*j.*)	.../..../..../..../	.../..../..../	/	(3 4 4 4 3 4 4 –)
(*k.*)	.../..../..../..../	..../..../..../	/	(3 4 4 4 4 4 4 –)
(*l.*)	..../..../..../..../	../..../..../	/	(4 4 4 4 2 4 4 –)
(*m.*)	..../..../..../..../	.../..../..../	/	(4 4 4 4 3 4 4 –)
(*n.*)	..../..../..../..../	..../..../..../	/	(4 4 4 4 4 4 4 –)

Variation 2.

Subvariation—

(*a.*)	../ ../ ../ ../	./ ../ ../	/	(2 2 2 2 1 2 2 –)
(*b.*)	../ .../ .../ .../	./ .../ .../	/	(2 3 3 3 1 3 3 –)
(*c.*)	../..../..../..../	./..../..../	/	(2 4 4 4 1 4 4 –)
(*d.*)	.../ .../ .../ .../	./ .../ .../	/	(3 3 3 3 1 3 3 –)
(*e.*)	.../..../..../..../	./..../..../	/	(3 4 4 4 1 4 4 –)
(*f.*)	..../..../..../..../	./..../..../	/	(4 4 4 4 1 4 4 –)

Variation 3.

Subvariation—

(*a.*)	../ ../ ../ ../.	../ ../ ../	/	(2 2 2 2 3 2 2 –)
(*b.*)	../ .../ .../ .../.	.../ .../ .../	/	(2 3 3 3 4 3 3 –)
(*c.*)	../..../..../..../.	..../..../..../	/	(2 4 4 4 5 4 4 –)
(*d.*)	.../ .../ .../ .../.	.../ .../ .../	/	(3 3 3 3 4 3 3 –)
(*e.*)	.../..../..../..../.	..../..../..../	/	(3 4 4 4 5 4 4 –)
(*f.*)	..../..../..../..../.	..../..../..../	/	(4 4 4 4 5 4 4 –)

Variation 4.

Subvariation—

(*a.*)	../ ../ ../ ../..	../ ../ ../	/	(2 2 2 2 4 2 2 –)
(*b.*)	../ .../ .../ .../..	.../ .../ .../	/	(2 3 3 3 5 3 3 –)
(*c.*)	../..../..../..../..	..../..../..../	/	(2 4 4 4 6 4 4 –)
(*d.*)	.../ .../ .../ .../..	.../ .../ .../	/	(3 3 3 3 5 3 3 –)
(*e.*)	.../..../..../..../..	..../..../..../	/	(3 4 4 4 6 4 4 –)
(*f.*)	..../..../..../..../..	..../..../..../	/	(4 4 4 4 6 4 4 –)

GROUP B and
GROUP C.

The same remarks apply in Ballad that applied in Romance metre—that is, the two groups are the same as GROUP A except that they have feminine and double-feminine endings respectively.

DIVISION II.

This again, as in Romance, differs from DIVISION I only in that the verses all begin *abruptly*, or with a stressed syllable.

3. NIBELUNGEN METRE.

DIVISION I.
GROUP A.
Variation 1.
Subvariation—

(*a.*)	../ ../ ../.	/ ../ ../ ../	/	(2 2 2 + 2 2 2 –)
(*b.*)	../ .../ .../.	/ ../ .../ .../	/	(2 3 3 + 2 3 3 –)
(*c.*)	../ .../ .../.	/ .../ .../ .../	/	(2 3 3 + 3 3 3 –)
(*d.*)	../..../..../.	/ ../..../..../	/	(2 4 4 + 2 4 4 –)
(*e.*)	../..../..../.	/ .../..../..../	/	(2 4 4 + 3 4 4 –)
(*f.*)	../..../..../.	/..../..../..../	/	(2 4 4 + 4 4 4 –)
(*g.*)	.../ .../ .../.	/ ../ .../ .../	/	(3 3 3 + 2 3 3 –)
(*h.*)	.../ .../ .../.	/ .../ .../ .../	/	(3 3 3 + 3 3 3 –)
(*i.*)	.../..../..../.	/ ../..../..../	/	(3 4 4 + 2 4 4 –)
(*j.*)	.../..../..../.	/ .../..../..../	/	(3 4 4 + 3 4 4 –)
(*k.*)	.../..../..../.	/..../..../..../	/	(3 4 4 + 4 4 4 –)
(*l.*)	..../..../..../.	/ ../..../..../	/	(4 4 4 + 2 4 4 –)
(*m.*)	..../..../..../.	/ .../..../..../	/	(4 4 4 + 3 4 4 –)
(*n.*)	..../..../..../.	/..../..../..../	/	(4 4 4 + 4 4 4 –)

Variation 2.
Subvariation—

(*a.*)	../ ../ ../.	/ ./ ../ ../	/	(2 2 2 + 1 2 2 –)
(*b.*)	../ .../ .../.	/ ./ .../ .../	/	(2 3 3 + 1 3 3 –)
(*c.*)	../..../..../.	/ ./..../..../	/	(2 4 4 + 1 4 4 –)
(*d.*)	.../ .../ .../.	/ ./ .../ .../	/	(3 3 3 + 1 3 3 –)
(*e.*)	.../..../..../.	/ ./..../..../	/	(3 4 4 + 1 4 4 –)
(*f.*)	..../..../..../.	/ ./..../..../	/	(4 4 4 + 1 4 4 –)

GROUP B and
GROUP C.

Again the remark concerning these groups in Romance and Ballad metres apply.

DIVISION II.

As in Romance and Ballad, the verses in this division begin abruptly.

4. ALEXANDRINE METRE.

DIVISION I.
GROUP A.
Variation 1.
Subvariation—

(*a.*)	../ ../ ../	/ ../ ../ ../	/	(2 2 2 2 2 2 –)
(*b.*)	../ .../ .../	/ ../ .../ .../	/	(2 3 3 2 3 3 –)
(*c.*)	../ .../ .../	/ .../ .../ .../	/	(2 3 3 – 3 3 3 –)
(*d.*)	../..../..../	/ ../..../..../	/	(2 4 4 – 2 4 4 –)
(*e.*)	../..../..../	/ .../..../..../	/	(2 4 4 – 3 4 4 –)
(*f.*)	../..../..../	/..../..../..../	/	(2 4 4 – 4 4 4 –)
(*g.*)	.../ .../ .../	/ ../ .../ .../	/	(3 3 3 – 2 3 3 –)
(*h.*)	.../ .../ .../	/ .../ .../ .../	/	(3 3 3 – 3 3 3 –)
(*i.*)	.../..../..../	/ ../..../..../	/	(3 4 4 – 2 4 4 –)
(*j.*)	.../..../..../	/ .../..../..../	/	(3 4 4 – 3 4 4 –)
(*k.*)	.../..../..../	/..../..../..../	/	(3 4 4 – 4 4 4 –)
(*l.*)	..../..../..../	/ ../..../..../	/	(4 4 4 – 2 4 4 –)
(*m.*)	..../..../..../	/ .../..../..../	/	(4 4 4 – 3 4 4 –)
(*n.*)	..../..../..../	/..../..../..../	/	(4 4 4 – 4 4 4 –)

Variation 2.

Subvariation—

(*a.*)	../ ../ ../ /	./ ../ ../ /	(2 2 2 – 1 2 2 –)
(*b.*)	../ .../ .../ /	./ .../ .. / /	(2 3 3 – 1 3 3 –)
(*c.*)	../..../..../ /	./..../... / /	(2 4 4 – 1 4 4 –)
(*d.*)	. ./ .../ .../ /	./ .../ .. / /	(3 3 3 – 1 3 3 –)
(*e.*)	.../..../...., /	./..../..../ /	(3 4 4 – 1 4 4 –)
(*f.*)	..../..../..../ /	./..../..../ /	(4 4 4 – 1 4 4 –)

GROUP B and
GROUP C.

Again the remark concerning these groups in Romance, Ballad, and Nibelungen apply.

DIVISION II.

As in Romance, Ballad, and Nibelungen, the verses in this division begin abruptly.

DIVISION III.

In this division may be classed the "unpaused" Alexandrine:—

../../../../../../ / / (2 2 2 2 2 2 – –)

This can vary only at opening and close, with ordinary duple, triple, or quadruple, or abrupt, at the former, and feminine or double-feminine at the latter.

In the foregoing groups will be included all poems whose stanzas are *regular;* stanzas, that is, composed of a definite number of *full verses.* To each group will be appended one or more subgroups where an exceptional construction is met with, as in the following:—

Winds are loud and you are dumb,
Take my love, for love will come,
  Love will come but once a life.
Winds are loud and winds will pass!
Spring is here with leaf and grass:
  Take my love and be my wife.
After loves of maids and men
Are but dainties drest again:
Love me now, you'll love me then:
  Love can love but once a life.

(*Tennyson,* "No Answer" from "The Window.")

When, dearest, I but think of thee,
  Methinks all things that lovely be
Are present, and my soul delighted:
  For beauties that from worth arise
  Are like the grace of deities,
Still present with us, though unsighted.

(*Sir John Suckling,* "A Song.")

The construction of these is similar to the construction of the Dowsabel stanza, but the effect is entirely different. The whose difference lies in the third and sixth lines, which in the two above examples contain four stresses, against three in the Dowsabel. The former will therefore more naturally fall into Division I of the Romance metre, under variation 1 of Group A; the latter into the parallel division of Ballad metre. A fuller discussion concerning exceptional forms will be more in place in the chapter on the stanza.

Art. LVI.—*New Zealand Bird-song.*

By Johannes C. Andersen.

[*Read before the Philosophical Institute of Canterbury, 2nd November, 1910.*]

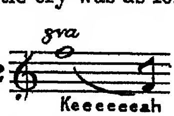
The following additional notes and variations have been observed since publication of the 1908 Transactions.

On the 12th November, 1909, in company with Mr. T. D. Burnett, of the Mount Cook Run Station, I climbed Mount Burnett, 6,234 ft. in height. On the western slope of the peak, at a height of over 5,500 ft., we found a quantity of moa gizzard-stones. They were quartz, and lay in an earth-filled pocket of rock, near an amphitheatre or half-basin, a formation commonly found among the weathered tops of this range, the Liebig, which is composed in great part of clay slates and sandstone. Many large moa-bones have been found on the lower parts of the run, the homestead of which is 1,900 ft. above sea-level. On descending the eastern side we saw one kea just below the snow-line. Keas were formerly very numerous on this run, a tally kept for thirteen years showing an average loss of five hundred sheep a year through their attacks alone: the flock runs from five to six thousand. The consequence is, unrespited war against them has very considerably reduced the numbers of the kea. Mr. Burnett told me that it has a greater variety of calls than any other bird known to him. When worrying a sheep it emits a detestable chuckling sound; and he has lain through a night in an out-hut hearing this sound, exasperated at being unable to interrupt the feast he knew was going on above him. There was a high wind blowing when we saw this solitary kea, but, as the bird stayed close to us for a considerable time (thanks to the forbearance of my host), I was able to take the pitch of his characteristic cry.

1 

1a 

No. (1) was the most frequent cry. It is most plaintive, as if the bird were the injured party. The cry differs at various times in several ways. Sometimes the slur is from a short note to a longer one, dropped a semitone, as (1); sometimes it is from a long note to a short one, without the semitone drop, as in (1*a*). This latter cry I heard several times over the moraine of the Tasman Glacier; and whereas (1) is plaintive, (1*a*) is more sinister. Again, the interval was often much less: it constantly varied, and was sometimes so slight that it sounded very like the mewing of a lost kitten. On the 18th November, 1910, we camped for a night at the terminal face of the Murchison Glacier, on the slopes of the Malte Brun Range, and before daylight on the 19th we heard several keas in the heights above. A most characteristic cry was as follows:—

2 

2a 

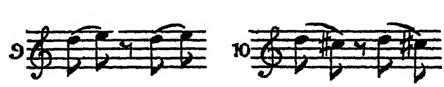
The first note of (2) was long drawn out on the *f*, and slurred vigorously down through an octave. No. (2*a*) was most curious: the long *d* was

uttered with a rapid vibrato, as though it were bubbling through water, and slurred to *f* as in (2). In both instances the intervals between the long note and the short note varied, the pitch being anything apparently between a third and an octave above *f*. If the name of the kea be onomatopoetic, as seems almost certain, it should be spelt *kia*, not *kea*.

A bird regarded with quite different feelings is the paradise duck (*Casarca variegata*—putangitangi). This is very common on the Jollie and great Tasman River beds, and is never molested. It is a beautiful bird, and I never saw it but in pairs. The cries of the duck and drake are quite distinct.

Nos. (1) to (5) are cries of the duck. Her note varies exceedingly in pitch, sequence, combination, and duration. The notes are uttered both whilst at rest and on the wing. The sound is not a whistle, but is nearer a clear human cry, especially as regards No. (5). The drake's note is very different. It is represented in (6). The sound differs altogether from that of the duck—it can be very nearly reproduced with a piece of paper and a comb. There is an overtone of a third distinctly audible, and this overtone, very much softer and fainter than the deeper note, has a sound more allied to the cry of the duck. I did not hear this note of the drake's varied in 1909, but on the 16th and 17th November, 1910, in the same locality, it was varied as under :—

The quality of the note is as in (6), but the overtone is absent. It was repeated twice or oftener, both whilst the drake was at rest and on the wing. On the 21st November, 1910, I noted the following variations in the cry of the duck :—



She uttered the cry (9) whilst walking on the river-bed, changing to (10) on taking to the wing, and returning to (9) again whilst on the wing. Very often during flight the drake sounded his deep note whilst the duck cried the notes of (5), and one could not help imagining that she was then lamenting a lost brood or desolated home, whilst the old drake, with tears in his voice, was doing his utmost to comfort her. If, as is said, the native name "putangitangi" was given on account of the cry, then (5) is certainly the note whose plaintiveness touched the poetical nature of the dusky name-giver. Whilst on the Jollie River bed a duck suddenly appeared

before us, fluttering away on the shingle as if wounded and in the last extremity. "There's a nest somewhere," said my companion, "and she is decoying us away from it." We humoured her maternal instinct, and after preceding us for a dozen yards or so she rose in the air and flew off.

Whilst resting after breakfast on the lateral moraine of the Tasman Glacier at the southern end of the Murchison Valley, on the 19th November, 1910, we were much pleased by the actions of a paradise duck and drake. A clear, gentle stream flowed along the foot of the moraine at our feet, and the duck waded fearlessly backwards and forwards not more than 15 ft. from us. She approached nearer and nearer each traverse, until she was no more than 8 ft. away. As she moved she constantly emitted a quiet, pleasing sound, the quack (though the term is too hard) of the paradise. After a time she rejoined her mate on the gravel beyond the stream, where they both settled down to sleep in the morning sun. We were delighted with their tameness: it gave us excellent opportunity of noting and admiring the beauty of their plumage. This Murchison Valley was extremely quiet: it has never been ent red by stock of any kind, and bird-life was also very scarce at the time of our visit. Besides half a dozen paradise ducks, we saw only two seagulls, and heard the keas above mentioned. At dawn of the 19th, too, away up at the Murchison terminal, we heard a blackbird in the Malte Brun scrub, and lower down two more blackbirds and a ubiquitous chaffinch—an extremely common bird.

I was at Stony Bay, near Okain's, Banks Peninsula, late in December of 1909, and a solitary pair of paradise ducks had nested and brooded in the valley—a most unusual occurrence.

The blue duck (*Hymenolaemus malacorhynchus*—whio) is now rare, even on the river-beds away in the mountains, where it was formerly extremely common. It is too good a table-bird to escape the common run of rabbiter and station hand. I saw none in 1909; but on the 15th November 1910, whilst riding down the Jollie, I made the acquaintance of a pair. They were floating down the rapid stream, bobbing about on the broken water, apparently entirely at the mercy of the current; but by some dexterous movement both shot sideways out of the swift water into a comparative still stream behind a big rock. Here they dived and probed with their beaks for a time, when one made a dash at the rock, mounted half-way to its top, but slipped back into the water. It made a detour, and soon both were seated on the rock, preening their feathers. I dismounted, hoping to obtain a nearer view, and the birds allowed me to approach to within a few yards. In colour they were slaty blue, almost the colour of the water; their breasts were bronze; their bills pale yellow, almost white. Their note was a highly pitched cry—hardly a whistle:—

One of them uttered the cry in (1) three times whilst they were in the still pool diving and probing. It is a rapid vibrato, not a trill, and the duck thrusts out its neck when uttering the cry. It was varied as in (2), the quality of the note being the same.

We saw two grey ducks, but they were silent.

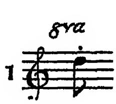
A very common bird on the Tasman River bed is the dottrel (*Octhodromus obscurus*—tuturiwatu). Its constant cry, which I did not hear varied in 1909, was *a* in alt, slurred to *a* flat :—

This is an agreeable whistle, repeated at intervals. In 1910 (November) its cry as it ran before me on the river-bed was constantly *a* repeated at intervals :—

On the 18th November, whilst riding from the Hermitage, we started a young dottrel from the tussock, and it would persist for a long distance running before the horses, stumbling occasionally, but keeping up an amazing speed for so small and young a bird. Eventually it took to the tussocks again.

On the 20th November, whilst riding along the river-bed track on the Tasman, three miles from Mount Cook homestead, we started (or should it be "flushed"?) a dottrel. It arose almost at our feet, and we suspected we had disturbed a hen on her nest; but, search as we would, we were unable to find it. Next day my companion passed along the same way, and again the bird rose. He waited at some distance, and had the pleasure of seeing her return to her nest. It was immediately beside the track, sheltered by a tussock; and, whilst artfully concealed, it was a wonder it had never been seen or trodden on, as the track is in almost daily use. The nest contained three dark-brown eggs, blotched with intensely dark brown, almost black, and they lay imbedded, not loose, in the nest. They were about the size of a starling's egg.

The graceful sea-marten, or sea-swallow (?), is fairly plentiful on the river-beds, though not so common as the dottrel. It is hailed in the back stations as the harbinger of spring. Its cry is usually a sharp whistle, as in (1) :—

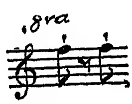


I heard the cry No. (2) on the 25th November, 1910, when the bird was flying over the Fork River, on the Mackenzie Plains. It was repeated at intervals as the bird flew by. No. (3) I heard on the 15th November, on the Jollie River. There were four or five swallows wheeling round together, and, all coming close together on one occasion, they wheeled downwards whilst one uttered this quick gurgling cry, running down in chromatic sequence from *d* to *g*.

On the same day we saw two beautiful redbills (*Haematopus unicolor-torea*). Their cry is very simple, merely a sharply sounded *f* :—

The sound may be represented by the letters *tsip*, ending on the first part of the *p* (with lips closed). It was uttered both on the wing and at rest. One bird, which my companion, Mr. Burnett, said was a young one, had the same note, a semitone lower.

In the early morning of the same day, thirteen miles up the Jollie River, in Pinnacle Creek, we saw a native lark (*Anthus novae-zealandiae*—pihoihoi). A light snow was falling at the time, and the bird settled on a big rock close by, bobbing its tail up and down as he whistled an *f*, somewhat similar to the note of the redbill, but unlettered :—



On the lower course of the Jollie that morning Mr. Burnett pointed out, as we rode, that on each of five large rocks standing up at intervals along the river a seagull was standing sentinel. We crossed the Tasman on the 24th November, and had just crossed a fair stream in mid-channel when we noticed half a dozen black-billed gulls (*Larus bulleri*) wheeling above us, making great clamour. Besides the common cry shown in No. (1), one of the birds at least constantly and shrilly emitted the cry No. (2) :—

We presently saw the reason. Two young downy birds, scarcely able to run, for they constantly stumbled and fell on the sand, the river there being free from stones, were scurrying away from us towards the stream, into which they plunged. They were then in their element, for they swam perfectly, and had soon placed the stream between them and the supposed source of danger, when they stumbled up the sand on the other side. They were simply little balls of grey-brown down, and each could easily have been contained in a small teacup.

On the 18th November, 1909, I was on the west side of the Tasman River, in the bush on Bush Creek. Here I heard a single grey-warbler three times, and each time he sang the following variation of the usual warbler sequence :—

Here, in so far as the notes are in triplets, the scheme is similar to that of the variations (3) and (4) in the Transactions of 1908. The difference is

that a rest takes the place of the last two notes of every alternative triplet. Each of the three times I heard the variation it was as above. A month afterwards I heard a somewhat similar variation in the Stony Bay Bush, viz. :—

6 

This was sung by itself, or as an introduction to the ordinary rambling indeterminate song : in the latter case, when the ordinary song commenced, it was on *a*, a drop of a third. Sometimes the town song, varied to triplets (8), introduced the variation (7), or the latter was often sung as an independent fragment—

7 

8 

I had read in Buller's "Manual of the Birds of New Zealand" that "Layard compares the note of the grey-warbler to the creaking sound of a wheelbarrow." I was never able to imagine which of the warbler notes induced this unmelodious simile. It was probably (7) ; but, whilst the pitch and slight occasional variation from *g* to *f* may coincide with the squeak of the wheelbarrow, there is absolutely no resemblance in the quality of the sound : the warbler's is sweet; the barrow's is shrill. The simile may also have been induced by No. (9), following :—

9 

This song hovered about *a* flat, a semitone above or below, the phrases of three triplets being separated by a short rest.

For the second time I had the pleasure of seeing a warbler whilst actually singing. The first I saw sat still, devoting all its energy to its song ; this one, on the contrary, moved briskly about in an apple-tree, prying under the still remaining autumn leaves, and whilst thus busily searching for its food it kept up the continuous minor melody. On the 28th March I noted a variation, as under :—

10 

This is the ordinary town song, varied in the second and third notes. These are usually semiquavers, both of the same pitch as the opening note ; here

they form a triplet, the middle note being a third below the others. Later in the season I noted the following :—

11 

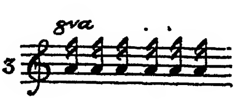
This, again, is the commoner song in triplets, varied by the omission of the third note of two of the triplets and the dropping of the third note of the third odd triplet, as above. The dropped note, *f*, in the above is usually softer than the others, so it may be that in cases where the notes appear to be omitted they may be only very subdued. I heard on the 27th March a call and reply which, from the pitch of the notes, their quality, and the appearance of the birds, I took to be warblers' :—

12 

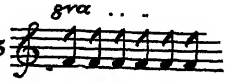
I saw the bird uttering the call, and heard the reply several times before the second bird appeared. They sat together on the same bough for a few seconds, and then flew off without giving further notes of identification.

I visited the Stony Bay bush again in December, 1910, and several times heard the warbler open its song with the fantail's *tweet-a-tweet*, or *tweet-a-tweet, tweet, tweet-a-tweet-tweet.* I again saw one whilst actually singing, and it behaved as described with variation (2) in 1908 Transactions. The song usually lasts about five seconds; I heard one that went on for eight, and one for twelve seconds.

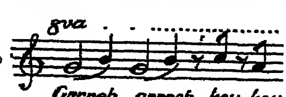
I heard several parrakeets in the Stony Bay Bush this year—December, 1909, and January, 1910—but only one new note, a quick chuckling cry, uttered when the bird was at rest in a tree :—

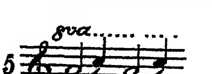
3 

Moreporks were also plentiful. One evening I heard two crying together. The sounds came from the same direction, but I could not say if the birds were together. The one emitted the ordinary cry of "More-pork," *a* flat to *g*; the other repeated *f* :—

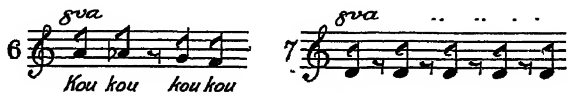
3 

On the evening of Christmas Day, 1910, I heard the following calls :—

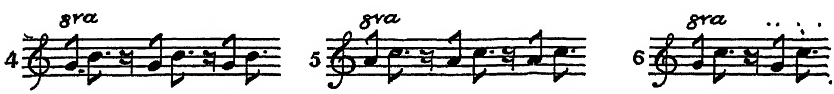
4 

5 

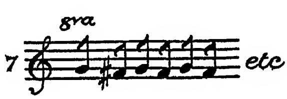
This (4) was a slurred cry, vibrato, and sounded like *greh* (German *r*), followed by *kou kou;* (5) differed in the first cry. No. (6), following, was many times repeated, at intervals of about five seconds, the full cry of four notes being uttered in one second. There was a trace of vibrato, almost making the cry *krou krou* instead of *kou kou.* No. (7) varies the opening of (1) in pitch.—



Wekas were plentiful, their call varying considerably in pitch and interval. I noted the following differences in December, 1909.—

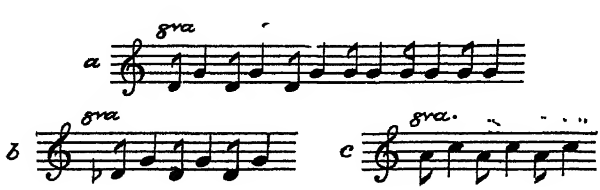


The following, sounded when the bird appeared to be running off, may be a danger-cry –



I this year heard the "drumming" sound emitted by the weka. It has been described as the sound made by knocking the head of an empty cask; it may also be described as the pizzicato of a double-bass violin. Sometimes, however, the note was sustained: on one occasion each note lasted for two seconds or more.

On the 2nd January I was particularly struck by the resemblance of some of the thrush's opening notes to the ordinary call of the weka. I had noticed this apparent imitation in the bays before, but not, so far as I can remember, about Christchurch. On several occasions I thought a weka called, but the call continued into a song, and I recognized my friend the thrush. I noted the following openings (all three were followed by full songs):—



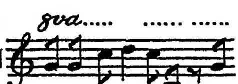
It will be noted that in one instance (c) the interval and pitch are exactly the same as the weka-call (5) above.

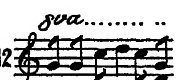
The bell-bird was either silent or there were very few in the bush this year: during a week I heard it only on one day, and then only four times. Neither was the tui so often heard. I noted that this year the gutturals were again *kree kraw krurr*, not *tiu tiu aurr*.

At the end of 1910, however, both tui and bell-bird were in exquisite song. This year the sweet explosive note (5) was *d* instead of *f*, and the bell-beat of (1) was *g* instead of *b* flat. The sound *aurr aurr* was constantly repeated, many times in succession. I saw one bird singing the soft bubbling song between the *aurr* sounds; its neck was outstretched, and the notes were soft, and highly pitched as a wren's. I was unable to distinguish any intervals—the notes glided one into the other; and there was little range—certainly not two tones. On the 25th December I heard two notes possessing a new quality:—

10 

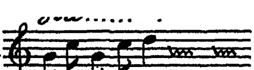
These notes bubbled like water running from a bottle, but they were melodious, and resonant, almost as a short string would be. On the 26th a tui kept up for several minutes an incessant *trr trr trr*, a dulled sound, somewhat like a cork being turned in the neck of a bottle. The sweet slur (2) was this year from *g* to *f*, and had a sound that may be represented by the letters *tweeah*. The following song was very common, all the variations being noted on the one day, the 26th December, 1910:—

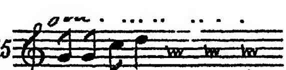
11 

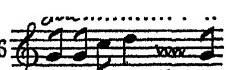
12 

13 

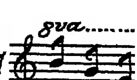
14 

14a 

15 

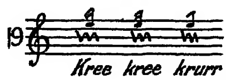
16 

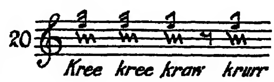
The usual song was as in No. (12), the concluding note being at times *g* and at times *e*. Often the concluding *g* was dropped an octave to the ordinary treble *g*; this was made quite evident when a high *g* followed the dropped note, as in No. (11). The last *g* had a sound like *gug*, but was very clear, open, and bell-like; it was separated from the preceding note by a pause twice as long as that note. Nos. (13) to (16) are simply variations of (12). It sounded curious to hear the *krau* breaking into the bell-like chime, as though the bird were clearing its throat (16). The effect was rather disagreeable; otherwise the chime is most beautiful. The usual song (12) occupied about a second and a half in utterance. On the 27th December the following was noted:—

17 

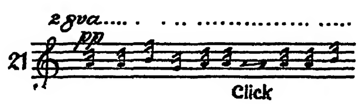
These three notes were full and deep, like a muted harp. The following is a variation of the usual bell note :—

Here each note was followed by a very light note, just audible, *two* octaves higher. The bell notes were this year followed by *kree kraw krurr*, with the following occasional variations : —



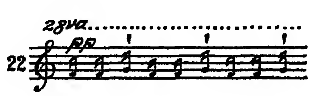


Here the notes inserted give the relative duration of the sounds. The sweet bubbling song was again heard. I took down the following :—



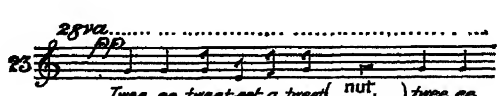
A curious *click* often broke the song ; or an explosive note, a sweet *d*, an octave lower than the bubble, would burst out, as though the bird were quite unable to suppress the full sweetness of its song altogether.

This year the vesper bell (7) was *g d*, *g d*, each pair being uttered in a second , the bell-like tone was perfect, most delightful to hear. I heard it on the 28th. And on that day, too, I saw two tuis in a totara, the one wooing or cajoling the other. The wooer sang the chime of (12) closely at the ear of his companion, following it with the high soft notes—



This was sung in a very subdued manner ; and, as the silent bird retreated, the other, singing, followed it flutter by flutter over short distances. Its cajoling was unsuccessful, however, so far as my observation went, for the one so sweetly persecuted flew off.

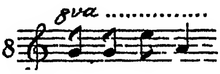
The high-pitched song was also varied as follows :—



The break in the song, which was almost vocal, was occupied by a sound which could be very well represented by the words *nut-cracker*.

I still found the notes of the bell-bird the most difficult of all to catch chiefly because they are so quickly uttered that I lost the first note by the time the last was sounded, and also because the pitch varies so considerably. The following songs were repeated at intervals on the 25th December; it occupied little, if anything, over a second in utterance:—

7 

8 

No. (8) was a very cheery song; and it is, like most of the notes of the bell-bird, much nearer a whistle than the bell-like notes of the tui; indeed, so far as I have heard, it is the tui that should be called the bell-bird.

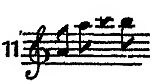
9 

In this song (9), there may be a drop to the *b* as there is to the *b* of (7); I could not distinguish for certain. As may be seen by the vocalization, however, the *b* of the two songs has each a different quality, the latter being much richer: whilst (7) is a whistle, (9) has more of a mellow flute sound; and the prolonged final *d* has certainly the suggestion of a sweet bell.

On this day, the 25th December, 1910, I heard a duet between a tui and a bell-bird. They sat in the same tree, a totara. The tui would beat his four or five bell notes, when the bell-bird would at once start the phrase (9), the *aurr aurr* of the tui forming the undersong. Sometimes the bell-bird allowed the *aurr aurr* to go unaccompanied.

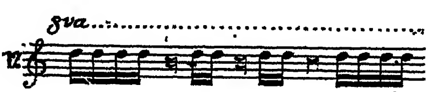
On the next day I heard a variation of No. (6):—

10 

11 

This variation (10) occupied a second and a half, perhaps less, in utterance. No. (11) introduces a very high note.

On the 28th December I heard a variation of (5), the twilight call to rest. Two or more birds joined, the combined chorus making a great noise. The sound was somewhat like the rapid unwinding of a fishing-reel. The variation runs as follows:—

12 

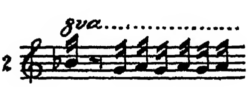
After hearing this call I left the darkening depths and sat at the edge of the bush to hear the last sounds. On most evenings the thrush was

exceedingly voluble, and I often almost anathematized the song that otherwise I so like to hear: it was out of place in the native bush; the thrush was an interloper. On this evening all was quiet at 8 o'clock, but at 8.15 a tui broke into the following pretty melody:—

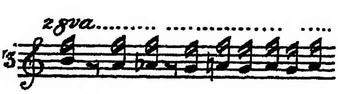
24 

The first two notes were loud and slurred; the following part was the bubbling song, its final *a* flat being drawn out, softening away into silence. A tui answered with (14*a*), omitting the *aurr aurr*, and dwelling longer on the final *d*; another answered with *kree kraw krurr*, whilst from a fourth came the full song of (12). That was the last sound of bird-song: the fantail, said to be the last bird heard in the evening, had ceased long since. Moths had begun fluttering in the deepening twilight, and low in the grass beetles kept up a most audible underhum on *f* (bass), some flying high and occasionally striking the leaves of the trees with a loud tap. A few drops of rain were falling, but, few as they were, their beating on the thousands of leaves emitted a faint murmur as of wind; but the leaves were quite unruffled; there was no wind whatever. At 8.35 came the first cry of the ruru; and at 8.40 a weka prophesied rain, which came heavily before morning.

On the 27th December I noted a variation of the song of the yellow-breasted tit:—

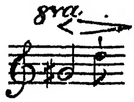
2 

and one on the 25th:—

3 

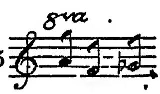
On the last day of 1909 I heard a new call. The note was much louder and shriller than any I had heard before, and I at once set off in the direction of the call, so as, if possible, to catch a glimpse of the new-comer. I located it high in a totara, and heard the call several times before I actually saw the bird. I at once concluded it was a cuckoo, a conclusion confirmed by subsequent correspondence with Dr. Fulton, of Dunedin, to whom I sent a description of the bird and its call. The bird appeared dark grey, long and thin, with long pointed beak, and when on the wing it looked like a flying cross with depressed arms. Once, as the bird left the high branches of a totara, its tail, which seemed about a foot long, was spread fanwise for a few moments. It was a long-tailed cuckoo (*Urodynamis taitensis*—koekoea). and my inability to distinguish its colour-marks was due to the

height it maintained when I saw it, and my own myopic eyes. The call was most distinctive : -

1 

2 

It opened on a sustained and swelled *g* sharp, which was deliberately slurred up to *d*, on which it abruptly ended, as represented in (1). I fancied I could hear an overtone of an octave in the *g*, but as the note impinges very shrilly on the ear, with a burring throb somewhat like that produced by two dissonant whistles simultaneously sounded, I conclude the overtone to be either not quite an octave or a little over the octave—a semi- or quarter-tone one way or the other. In ruder similitude, it sounds as though the bird has a very quickly vibrating pea in its whistle. Happening to snap a dry branch with a sounding crack, off flew the cuckoo, uttering the danger-cry shown in (2) above. These notes are simple whistles, sounded in quick legato—that is, the notes blend without being slurred. I saw the bird several times afterwards, but never very clearly. Once two birds sat high in a totara, when I heard the subdued conversational notes—

3 

On the 3rd January, 1910, I heard the cry (1) from a clump of bush at the head of the Little Akaroa Valley, several miles distant in a direct line from the Stony Bay Valley, so that this year the cuckoo was not uncommon on the Peninsula, though I was told it was several years since one had been seen in the Stony Bay Bush.

The cuckoo was again present in December, 1910. I heard it only on two or three occasions, and on one of these the call was *g* slurred to *b* :—

3 

I secured a pretty variation of. the song of the supposed hedge-sparrow recorded in 1908 :—

3 

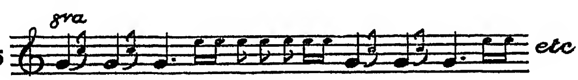
I record it as it has been suggested that the bird may be a native—the brown creeper (*Finschia novae-zelandiae*—toitoi)—though I am doubtful.

Fantails and grey-warblers have been very plentiful in the eastern parts of Christchurch this season ; wax-eyes not so plentiful. I have never before, in the bush or elsewhere, heard the fantail so full of song as during April

and half of each month before and after. Previously I had rather a poor opinion of the bird as a songster, though a high opinion of him as a cheery companion. I can thoroughly appreciate the choice of Maui, the Sun-god, when he induced the small birds of the forest to accompany him on his last and greatest adventure—the conflict with the Great Woman of Night, the Western Darkness. And it is said that it was the laughter of a cheery fantail that awoke the Woman of Night to a sense of her danger—alas for Maui! On the morning of the 6th April, 1910, I awoke at the day-spring, and a fantail was singing vigorously just outside my bedroom-window :—

4 

The notes were still the constricted, almost vocal sounds previously described, excepting the high *e*, which was nearer a sweet, pleasant whistle. Easter thoughts and feelings permeated all things, and the fantail's song at once carried me back to the days when, as a boy, Good Friday morning meant tea and hot buns in bed before getting-up time. I can well remember lying dozing, waiting to hear in the street outside, "Hot-cross-buns—ting-a-ling, ting-ting, ting-a-ling." This fantail's song was exactly like the cry and bell of the H.C.B. man. I listened to it with pleasure for some time: sometimes it opened with the common *tweet-a-tweet-a-tweet*, sometimes directly on *g*. I heard a much more frequent variation of this song many times during the autumn :—

5 

Here the lower notes were all *g*, the first two followed by a quick slur up to *c*, resulting in a pleasing variation of the *tweet*. The high notes *e* were almost invariably much softer and of less volume than the lower *g*, *f*, *e*, or *g*.

ART. LVII.—*On Centroidal Triangles.*

By EVELYN G. HOGG, M.A., F.R.A.S., Christ's College, Christchurch.

[*Read before the Philosophical Institute of Canterbury, 7th December, 1910.*]

1. LET the side BC of any triangle ABC be divided internally in the point X′ and externally in the point A′ in the ratio $p : q$; let CA, AB be similarly divided in the points Y′, B′ and Z′, C′ respectively. The triangles X′Y′Z′, A′B′C′ are termed "centroidal" triangles, inasmuch as the centroids of these triangles are coincident with that of the triangle of reference ABC.

The co-ordinates of the points X′, Y′, Z′ are respectively

$$\left(o,\ \lambda\frac{q}{b},\ \lambda\frac{p}{c}\right),\ \left(\lambda\frac{p}{a},\ o,\ \lambda\frac{q}{c}\right),\ \left(\lambda\frac{q}{a},\ \lambda\frac{p}{b},\ o\right)$$

where $\lambda = \frac{2\Delta}{p+q}$, Δ being the area of the triangle of reference.

The co-ordinates of the points A′, B′, C′ are respectively

$$\left(o,\ \mu\frac{q}{b},\ \mu\frac{p}{c}\right),\ \left(\mu\frac{p}{a},\ \mu\frac{q}{b},\ o\right),\ \left(\mu\frac{q}{a},\ \mu\frac{p}{b},\ o\right)$$

where $\mu = \frac{2\Delta}{p-q}$.

It follows that the co-ordinates of the centroids of the triangles X′Y′Z′, A′B′C′ are $\left(\frac{2\Delta}{3a}, \frac{2\Delta}{3b}, \frac{2\Delta}{3c}\right)$, which are those of the centroid of the triangle ABC. Since this result is independent of p and q we see that all triangles formed in this manner are co-centroidal with the triangle ABC.

Let now the sides Y′Z′, Z′X′, X′Y′ be divided in X_o, Y_o, Z_o so that

$$Y'X_o : X_oZ' = Z'Y_o : Y_oX' = X'Z_o : Z_oY' = p : q,$$

then the co-ordinates of the points X_o, Y_o, Z_o are respectively

$$\left(\frac{2\nu pq}{a}, \frac{\nu p^2}{b}, \frac{\nu q^2}{c}\right),\ \left(\frac{\nu q^2}{a}, \frac{2\nu pq}{b}, \frac{\nu p^2}{c}\right),\ \left(\frac{\nu p^2}{a}, \frac{\nu q^2}{b}, \frac{2\nu pq}{c}\right)$$

where $\nu = \frac{\lambda}{p+q} = \frac{2\Delta}{(p+q)^2}$.

Hence the triangle $X_oY_oZ_o$ is also co-centroidal with the triangle ABC. This result also holds for a triangle similarly formed by dividing the sides of the triangle A′B′C′, and the process may evidently be continued indefinitely.

2. The following simple relations may be easily proved :—

If Δ, Δ', $\Delta_{\prime}$ be the areas of the triangles ABC, X′Y′Z′, A′B′C′ respectively, then

$$\Delta' = \frac{p^2 - pq + q^2}{(p+q)^2}\,\Delta$$

$$\Delta_{\prime} = \frac{p^2 + pq + q^2}{(p-q)^2}\,\Delta.$$

If $\Delta' = n\Delta$, the minimum value of n is $\frac{1}{4}$, in which case $p = q$, and the triangle X′Y′Z′ is the medial triangle of the triangle ABC.

The triangles AY′Z′, BZ′X′, CX′Y′ are equal in area, the common value being $\frac{pq}{(p+q)^2}\,\Delta$.

The triangles AB′C′, BC′A′, CA′B′ are equal in area, the common value being $\frac{pq}{(p-q)^2}\,\Delta$.

The centroids of the triangles AY′Z′, AB′C′, as the ratio $p : q$ varies, lie on straight lines parallel to BC and bisecting AG, where G is the centroid of the triangle ABC.

The middle points of the sides of all centroidal triangles lie on the sides of the medial triangle of the triangle ABC.

If the sides of the triangles X′Y′Z′, A′B′C′ be respectively x', y', z' and a', b', c'

$$\Sigma\,(x'^2) = \frac{p^2 - pq + q^2}{(p+q)^2}\,\Sigma\,(a^2)$$
$$\Sigma\,(a'^2) = \frac{p^2 + pq + q^2}{(p-q)^2}\,\Sigma\,(a^2).$$

If p_1, p_2, p_3 be the perpendiculars from G on the sides of a centroidal triangle, and p', p'', p''' the perpendiculars on those sides from A, B, C, then

$$\frac{p_1}{p'} = \frac{p_2}{p''} = \frac{p}{p'''}.$$

The equation of the circle circumscribing any centroidal triangle is

$$\begin{gathered}(\lambda - 1)(\lambda^2 - 1)\,abc\,(a\beta\gamma + b\gamma\alpha + c\alpha\beta)\\ +\ \lambda\,(a\alpha + b\beta + c\gamma)\,[a\alpha\,(a^2\lambda + b^2\lambda^2 + c^2) + b\beta\,(a^2 + b^2\lambda + c^2\lambda^2) + c\gamma\,(a^2\lambda^2\\ + b^2 + c^2\lambda)] = o,\end{gathered}$$

and the radical axis of this circle and of the circle ABC envelops, as λ varies, the conic

$$\begin{gathered}(a^4 - 4b^2c^2)\,a^2\alpha^2 + (b^4 - 4c^2a^2)\,b^2\beta^2 + (c^4 - 4a^2b^2)\,c^2\gamma^2\\ - 2\,(2a^4 + b^2c^2)\,bc\beta\gamma - 2\,(2b^4 + c^2a^2)\,ca\gamma\alpha - 2\,(2c^4 + a^2b^2)\,ab\alpha\beta = o.\end{gathered}$$

The locus of the symmedian point of the triangle AY′Z′ is the curve

$$2bc\,(c\beta^3 + b\gamma^3) - c\,(c^2 - a^2)\,\beta^2\gamma + b\,(a^2 - b^2)\,\beta\gamma^2 = abcd\beta\gamma.$$

3. The equations of the lines B′C′, C′A′, A′B′ are respectively

$$\begin{aligned}L' &\equiv pqa\alpha + q^2b\beta + p^2c\gamma = o\\ M' &\equiv p^2a\alpha + pq\,b\beta + q^2c\gamma = o\\ N' &\equiv q^2a\alpha + p^2b\beta + pqc\gamma = o,\end{aligned}$$

while those of Y′Z′, Z′X′, X′Y′ are respectively

$$\begin{aligned}L_1 &= -pq\,a\alpha + q^2b\beta + p^2c\gamma = o\\ M_1 &= p^2a\alpha - pq\,b\beta + q^2c\gamma = o\\ N_1 &= q^2a\alpha + p^2b\beta - pqc\gamma = o.\end{aligned}$$

Hence as the ratio $p : q$ varies, the lines L′, L_1; M′, M_1; N′, N_1 envelop respectively the parabolas

$$\begin{aligned}S' &\equiv a^2\alpha^2 - 4bc\beta\gamma = o\\ S'' &\equiv b^2\beta^2 - 4ca\gamma\alpha = o\\ S''' &\equiv c^2\gamma^2 - 4ab\alpha\beta = o.\end{aligned}$$

The points of contact of L′ and L_1 with S′ are respectively

$$\left(-\frac{2pq}{a}, \frac{p^2}{b}, \frac{q^2}{c}\right),\ \left(\frac{2pq}{a}, \frac{p^2}{b}, \frac{q^2}{c}\right);$$

hence the sides of any centroidal triangle are divided internally and externally in the same ratio at the points in which they touch their enveloping parabolas.

The lines L′, L_1 intersect on BC; M′, M_1 intersect on CA; and N′, N_1 intersect on AB. Calling these points of intersection A″, B″, C″ respectively, we have for the equations of the lines B″C″, C″A″, A″B″

$$L'' \equiv p^2q^2 a\alpha + p^4 b\beta + q^4 c\gamma = o$$
$$M'' \equiv q^4 a\alpha + p^2q^2 b\beta + p^4 c\gamma = o$$
$$N'' \equiv p^4 a\alpha + q^4 b\beta + p^2q^2 c\gamma = o.$$

Comparing the equations L″, M″, N″ with those of L′, M′, N′ we see that the triangle A″B″C″ is a centroidal triangle formed by dividing the sides of the triangle ABC in the ratio $q^2 : p^2$.

The area of the triangle A″B″C″ is given by

$$\Delta'' = \frac{p^4 + p^2q^2 + q^4}{(p^2 - q^2)^2}\,\Delta,$$

and therefore the areas of the triangles A″B″C″, A′B′C′, X′Y′Z′, and ABC are connected by the relation

$$\Delta'' \,.\, \Delta = \Delta' \,.\, \Delta_1.$$

If BC, CA, AB be divided internally in X″, Y″, Z″ so that (A″BX″C), (B″CY″A), (C″AZ″B) form harmonic ranges, we have a fourth centroidal triangle X″Y″Z″, inscribed in the triangle ABC, the equations of whose sides, L_2, M_2, N_2, may be formed from L″, M″, N″ by writing $-q^2$ for q^2 in the latter equations.

4. Let P′Q′R′, P″Q″R″, $P_1Q_1R_1$, $P_2Q_2R_2$ be respectively the poles of L′M′N′, L″M″N″, $L_1M_1N_1$, $L_2M_2N_2$ with regard to the triangles.

The co-ordinates of P′Q′R′ are proportional to

$$\left(\frac{1}{apq}, \frac{1}{bq^2}, \frac{1}{cp^2}\right), \left(\frac{1}{ap^2}, \frac{1}{bpq}, \frac{1}{cq^2}\right), \left(\frac{1}{aq^2}, \frac{1}{bp^2}, \frac{1}{cpq}\right).$$

These points are the vertices of the triangle formed by the lines AX′, BY′, CZ′; as the ratio $p : q$ varies the loci of these points are the ellipses

$$S_1 \equiv a^2\alpha^2 - bc\beta\gamma = o$$
$$S_2 \equiv b^2\beta^2 - ca\gamma\alpha = o$$
$$S_3 \equiv c^2\gamma^2 - ab\alpha\beta = o.$$

The lines AP′, BQ′, CR′ will meet S_1, S_2, S_3 respectively in P_1, Q_1, R_1. The position of P_1 may be found by observing that (B . AP′CP_1) is an harmonic pencil. Q_1 and R_1 may be found in a similar manner.

The lines BB′, CC′ meet in P_2; CC′, AA′ in Q_2; AA′, BB′ in R_2. P″, Q″, R″ may be found from P_2, Q_2, R_2 in the manner employed to determine $P_1Q_1R_1$.

The four triangles P′Q′R′, P″Q″R″, $P_1Q_1R_1$, and $P_2Q_2R_2$ have their centroids at the point G.

5. The lines L′, L_1 may be respectively written

$$L' \equiv pq\,(a\alpha + b\beta + c\gamma) - (p - q)(qb\beta - pc\gamma) = o$$
$$L_1 \equiv -pq\,(a\alpha + b\beta + c\gamma) + (p + q)(qb\beta + pc\gamma) = o.$$

The equations of AX′, AA′ are respectively

$$pb\beta - qc\gamma = o$$
$$pb\beta + qc\gamma = o.$$

Let lines drawn through A, B, C parallel respectively to L′M′N′ meet the opposite sides of ABC in D′E′F′. The equation of the line-pair AX′, AD′ will be

$$(pb\beta - qc\gamma)(qb\beta - pc\gamma) = o$$
$$pq\,(b^2\beta^2 + c^2\gamma^2) - (p^2 + q^2)\,bc\beta\gamma = o.$$

Hence the six points X′Y′Z′, D′E′F′ lie on the conic

$$S_o \equiv pq\,(a^2\alpha^2 + b^2\beta^2 + c^2\gamma^2) - (p^2 + q^2)(bc\beta\gamma + ca\gamma\alpha + ab\alpha\beta) = o.$$

We now proceed to show that this is the Steiner ellipse of the triangle X′Y′Z′—*i.e.*, the locus of points whose polars with respect to the triangle X′Y′Z′ pass through the point G. If $\frac{1}{a}, \frac{1}{b}, \frac{1}{c}$ be substituted for α, β, γ in L_1, M_1, N_1, these quantities have the common value $p^2 - pq + q^2$; hence the equation of the Steiner ellipse of the triangle X′Y′Z′ may be written

$$\frac{1}{L_1} + \frac{1}{M_1} + \frac{1}{N_1} = o.$$

This on multiplying out and dividing by the common factor $p^2 - pq + q^2$ reduces to S_o.

Let lines through ABC parallel to $L_1M_1N_1$ respectively meet the opposite sides of that triangle in $D_1E_1F_1$. Then the six points A′B′C′, $D_1E_1F_1$ lie on the conic

$$S_o' \equiv pq\,(a^2\alpha^2 + b^2\beta^2 + c^2\gamma^2) + (p^2 + q^2)(bc\beta\gamma + ca\gamma\alpha + ab\alpha\beta) = o,$$

and this conic is at once shown to be the Steiner ellipse of the triangle A′B′C′.

The envelope of the Steiner ellipses of centroidal triangles, as the ratio $p : q$ varies, is

$$(a\alpha + b\beta + c\gamma)^2\,(\sqrt{a\alpha} + \sqrt{b\beta} + \sqrt{c\gamma}) = o.$$

6. The circum-circle of the triangle AY′Z′ will for all values of the ratio $p : q$ pass through a fixed point. The equation of the circle in question is

$$p\,[(a^2 - b^2)\,\beta\gamma + ca\alpha\beta - bc\gamma^2] - q\,[(c^2 - a^2)\,\beta\gamma - ab\gamma\alpha + bc\beta^2] = o.$$

Hence this circle passes through the intersection of two fixed circles, which may be written

$$aS - b\gamma L = o$$
$$aS - c\beta L = o$$

where $S \equiv a\beta\gamma + b\gamma\alpha + c\alpha\beta$ and $L = a\alpha + b\beta + c\gamma$.

The former of these circles touches AC at A and passes through B; the latter circle touches AB at A and passes through C. The radical axis of these circles is $c\beta - b\gamma = o$, and this line meets the circles again in the point H′ $\left(\frac{2bc\cos A}{a}, b, c\right)$.

Hence since Y′Z′ envelops a parabola S′ which touches AY′ and AZ′, and the circum-circle of AY′Z′ always passes through a fixed point H′, that point must be the focus of $S' = o$.

Similarly it may be shown that the foci of the parabolas S′, S″ are at the points H″ $\left(a, \frac{2ca\cos B}{b}, c\right)$, H‴ $\left(a, b, \frac{2ab\cos C}{c}\right)$ respectively.

It is seen by inspection that if K be the symmedian point of the triangle ABC, then H′, H″, H‴ lie on AK, BK, CK respectively.

The trilinear ratios of the middle point of the chord of the circle ABC drawn from A through K are

$$\left(\frac{2bc\cos A}{a}, b, c\right).$$

Hence we see that the three foci H′, H″, H‴ lie on the Brocard circle or circle having as its diameter the line joining the centre of the circle ABC to the symmedian point K.

If F be the centre of the circle ABC, then H′ lies on the circle whose diameter is AF—viz., the circle

$$(c\beta + b\gamma)\,\mathrm{L} - 2a\,\mathrm{S} = o.$$

It may also be shown that the four points BCFH′ are concyclic.

If the tangent to the circle ABC at A meets BC in T, then H′ is the foot of the perpendicular from A on FT.

The equation of the Brocard circle may be written

$$abc\left(\frac{\alpha}{a} + \frac{\beta}{b} + \frac{\gamma}{c}\right)\mathrm{L} - \Sigma(a^2)\,.\,\mathrm{S} = o,$$

and it is easily seen that it is satisfied by the co-ordinates of H′, H″, and H‴.

7. If δ_1, δ_2, δ_3 be the medians drawn from A, B, C respectively to the middle points of the opposite sides of the triangle ABC, then the semi-latera recta of S′, S″, S‴ are respectively

$$\frac{\Delta^2}{\delta_1{}^3}, \frac{\Delta^2}{\delta_2{}^3}, \frac{\Delta^2}{\delta_3{}^3},$$

where Δ is the area of the triangle ABC.

Also, $$\mathrm{AH'} = \frac{bc}{2\delta_1}, \ \mathrm{BH'} = \frac{c^2}{2\delta_1}, \ \mathrm{CH'} = \frac{b^2}{2\delta_1},$$
whence $\mathrm{AH'^2} = \mathrm{BH'}.\mathrm{CH'}$.

We have $$\mathrm{AK} = \frac{bc}{\Sigma(a^2)}\,.\,2\delta_1,$$
and therefore $\mathrm{AH'}\,.\,\mathrm{AK} = \dfrac{b^2c^2}{\Sigma(a^2)}$

Hence if T′, T″, T‴ be the lengths of the tangents from A, B, C respectively to the Brocard circle,

$$a\mathrm{T'} = b\mathrm{T''} = c\mathrm{T'''} = \frac{abc}{\sqrt{\Sigma(a^2)}}.$$

The directrices of the parabolas S′, S″, S‴ are respectively

$$\mathrm{D}_1 \equiv a\cos \mathrm{A}\alpha - c\beta - b\gamma = o$$
$$\mathrm{D}_2 \equiv -c\alpha + b\cos \mathrm{B}\beta - a\gamma = o$$
$$\mathrm{D}_3 \equiv -b\alpha - a\beta + c\cos \mathrm{C}\gamma = o.$$

From the form of D_1 it is seen that it passes through the point in which the tangent at A to the circle ABC meets BC.

Let the vertices of the triangle formed by D_1, D_2, D_3 be $\mathrm{V}_1, \mathrm{V}_2, \mathrm{V}_3$.

The equations of the lines AV_1, BV_2, CV_3 are respectively

$$\beta\,(ca + b^2\cos \mathrm{B}) - \gamma\,(ab + c^2\cos \mathrm{C}) = o$$
$$\gamma\,(ab + c^2\cos \mathrm{C}) - \alpha\,(bc + a^2\cos \mathrm{A}) = o$$
$$\alpha\,(bc + a^2\cos \mathrm{A}) - \beta\,(ca + b^2\cos \mathrm{B}) = o.$$

Hence the triangle $V_1V_2V_3$ is in perspective with the triangle ABC, the centre of perspective being the isogonal conjugate of the point

$$[(bc + a^2 \cos A), (ca + b^2 \cos B), (ab + c^2 \cos C)],$$

which is the centre of the Brocard circle.

If p_1, p_2, p_3 be the lengths of the perpendiculars from V_1, V_2, V_3 respectively on the opposite sides of the triangle $V_1V_2V_3$, then

$$p_1\delta_1 = p_2\delta_2 = p_3\delta_3,$$

the common value of these products being

$$\frac{1}{3}[\Sigma(a^2) + D^2(1 + \cos A \cos B \cos C)].$$

If a_1, b_1, c_1 be the lengths of the sides of the triangle $V_1V_2V_3$, then

$$p_1a_1 = p_2a_2 = p_3a_3.$$

Hence the sides of the triangle formed by the directrices of the three parabolas S′, S″, S‴ are proportional to the medians of the triangle ABC.

8. Writing λ for $\frac{p}{q}$ we have as the equations of the sides of a centroidal triangle

$$\lambda^2 c\gamma + \lambda a\alpha + b\beta = o$$
$$\lambda^2 a\alpha + \lambda b\beta + c\gamma = o$$
$$\lambda^2 b\beta + \lambda c\gamma + a\alpha = o.$$

Let the condition now be determined that a triangle $(A_2B_2C_2)$, the parameter of whose sides is λ_2, may be inscribed in a triangle $(A_1B_1C_1)$ whose sides have the parameter λ_1.

Solving for the equation of the sides C_2A_2, A_2B_2 for the co-ordinates of the vertex A_2 we have

$$a\alpha : b\beta : c\gamma = o : -1 : \lambda_2.$$

Hence if A_2 lie on B_1C_1 we have the condition

$$\lambda_1^2\lambda_2 = 1.$$

The same condition holds that B_2 and C_2 lie on C_1A_1 and A_1B_1 respectively.

We may now find the locus of the intersection of the corresponding sides B_1C_1, B_2C_2

$$\lambda_1 a\alpha + b\beta + \lambda_1^2 c\gamma = o$$
$$\lambda_2 a\alpha + b\beta + \lambda_2^2 c\gamma = o,$$

and therefore

$$a\alpha : b\beta : c\gamma = -(\lambda_1 + \lambda_2) : \lambda_1\lambda_2 : 1.$$

Eliminating λ_1 and λ_2 between the above and the equation $\lambda_1^2\lambda_2 = 1$, we see that the intersection of corresponding sides (BC) lies on the cubic

$$b^3\beta^3 + c^3\gamma^3 + abc\alpha\beta\gamma = o.$$

Similarly the intersections of corresponding sides (CA) and (AB) lie on the cubics

$$c^3\gamma^3 + a^3\alpha^3 + abc\alpha\beta\gamma = o$$
$$a^3\alpha^3 + b^3\beta^3 + abc\alpha\beta\gamma = o$$

respectively.

9. Let D′E′F′, D″E″F″ be two centroidal triangles, and let the two corresponding (BC) sides—*i.e.*, those which touch $S' = o$—meet in the point D $(\alpha_0\beta_0\gamma_0)$

The equations of E′F′, E″F″ will be

$$\left.\begin{aligned}\lambda'^2 c\gamma + \lambda' a\alpha + b\beta &= o\\ \lambda''^2 c\gamma + \lambda'' a\alpha + b\beta &= o\end{aligned}\right\} \quad . \quad . \quad . \quad \text{(i)}$$

when λ', λ'' are the roots of the equation

$$\lambda^2 c\gamma_0 + \lambda a\alpha_0 + b\beta_0 = o.$$

The sides F′D′, F″D″ will be

$$\left.\begin{aligned}\lambda'^2 a\alpha + \lambda' b\beta + c\gamma &= o\\ \lambda''^2 a\alpha + \lambda'' b\beta + c\gamma &= o\end{aligned}\right\} \quad . \quad . \quad \text{(ii)},$$

and the sides D′E′, D″E″ will be

$$\left.\begin{aligned}\lambda'^2 b\beta + \lambda' c\gamma + a\alpha &= o\\ \lambda''^2 b\beta + \lambda'' c\gamma + a\alpha &= o\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(iii)}.$$

Let F′D′, F″D″ meet in E, and D′E′, D″E″ in F. The co-ordinates of E are given by

$$a\alpha : b\beta : c\gamma = 1 : -(\lambda' + \lambda'') : \lambda'\lambda'',$$

$$\text{but } \lambda' + \lambda'' = -\frac{a\alpha_0}{c\gamma_0},\ \lambda'\lambda'' = \frac{b\beta_0}{c\gamma_0},$$

and therefore

$$\alpha : \beta : \gamma = \frac{c}{a}\gamma_0 : \frac{a}{b}\alpha_0 : \frac{b}{c}\beta_0.$$

In the same way it may be shown that the co-ordinates of the point F are $\left(\frac{b}{a}\beta_0, \frac{c}{b}\gamma_0, \frac{a}{c}\alpha_0\right)$.

The equations of DE, EF, FD are respectively

$$\begin{aligned}a\alpha\, P_0 + b\beta\, Q_0 + c\gamma\, R_0 &= o\\ a\alpha\, R_0 + b\beta\, P_0 + c\gamma\, Q_0 &= o\\ a\alpha\, Q_0 + b\beta\, R_0 + c\gamma\, P_0 &= o\end{aligned}$$

where $P_0 \equiv a^2\alpha_0^2 - bc\beta_0\gamma_0$, $Q_0 \equiv b^2\beta_0^2 - ca\gamma_0\alpha_0$, $R_0 \equiv c^2\gamma_0^2 - ab\alpha_0\beta_0$. Hence if the point $(\alpha_0\beta_0\gamma_0)$ lie on any of the conics S_1, S_2, S_3, the sides of the triangle DEF will pass through the vertices of the triangle ABC.

We also see that if $(\alpha_0\beta_0\gamma_0)$ lie on the curve $f(\alpha\beta\gamma) = o$, then E and F will lie on the curves $f\left(\frac{c\gamma}{a}, \frac{a\alpha}{b}, \frac{b\beta}{c}\right) = o$ and $f\left(\frac{b\beta}{a}, \frac{c\gamma}{b}, \frac{a\alpha}{c}\right) = o$.

If the point D $(\alpha_0\beta_0\gamma_0)$ lie on the Steiner ellipse $\frac{1}{a\alpha} + \frac{1}{b\beta} + \frac{1}{c\gamma} = o$, then the points E, F will also lie on this ellipse. In this case we have

$$P_0 : Q_0 : R_0 = a\alpha_0 : b\beta_0 : c\gamma_0,$$

and it may be easily shown that the sides of the triangle DEF touch this conic

$$\sqrt{a\alpha} + \sqrt{b\beta} + \sqrt{c\gamma} = o.$$

If D lie on the conic $\sqrt{a\alpha} + \sqrt{b\beta} + \sqrt{c\gamma} = o$, so also will the points E and F, and the sides of the triangle DEF will envelop the conic

$$\sqrt{U} + \sqrt{V} + \sqrt{W} = o,$$

$$\begin{aligned}\text{where}\quad U &\equiv -a\alpha + b\beta + c\gamma\\ V &\equiv a\alpha - b\beta + c\gamma\\ W &\equiv a\alpha + b\beta - c\gamma.\end{aligned}$$

10. The equations of the sides of the secondary centroidal triangle PQR formed by joining the points of contact of L′, M′, N′ with S′S″S‴ respectively are

$$3p^2q^2 a\alpha + (p^4 + 2pq^3)\, b\beta + (q^4 + 2p^3q)\, c\gamma = o$$

and two others.

Writing $\lambda = \frac{p}{q}$ we have

$$\lambda^4 b\beta + 2\lambda^3 c\gamma + 3\lambda^2 a\alpha + 2\lambda b\beta + c\gamma = o.$$

The invariants I and J of this quartic are

$$\mathrm{I} \equiv \frac{3a^2\alpha^2}{4},\ \mathrm{J} \equiv \frac{1}{8}(6abc\,\alpha\beta\gamma - 2b^3\beta^3 - 2c^3\gamma^3 - a^3\alpha^3),$$

whence the envelope of the above line is

$$(a^3\alpha^3 + b^3\beta^3 + c^3\gamma^3 - 3abc\,\alpha\beta\gamma)(b^3\beta^3 + c^3\gamma^3 - 3abc\,\alpha\beta\gamma) = o,$$

whence we may infer that the envelope of the sides of the triangle PQR consists of the line at infinity, the point $\left(\frac{1}{a}, \frac{1}{b}, \frac{1}{c}\right)$, and the system of cubics

$$b^3\beta^3 + c^3\gamma^3 - 3abc\,\alpha\beta\gamma = o$$
$$c^3\gamma^3 + a^3\alpha^3 - 3abc\,\alpha\beta\gamma = o$$
$$a^3\alpha^3 + b^3\beta^3 - 3abc\,\alpha\beta\gamma = o.$$

11. The four common tangents of the conic $\mathrm{S}' \equiv a^2\alpha^2 - 4bc\beta\gamma = o$ and the circle $\mathrm{S} \equiv a\beta\gamma + b\gamma\alpha + c\alpha\beta = o$ form a cyclic quadrilateral.

The equation of the locus of the pole of the line $\lambda^2 c\gamma + \lambda\, a\alpha + b\beta = o$ with respect to the circle S is the conic

$$bc\,(c\beta + b\gamma)^2 - a^2\,(a\gamma + c\alpha)(b\beta + a\alpha) = o,$$

which may be written

$$a^2\mathrm{S} + bc\, l_1 l_2 = o$$

where
$$l_1 \equiv a\alpha + c\beta + b\gamma = o$$
$$\equiv \mathrm{L} - (b - c)(\beta - \gamma) = o$$
$$l_2 \equiv a\alpha - c\beta - b\gamma = o$$
$$\equiv \mathrm{L} - (b + c)(\beta + \gamma) = o,$$

L being the line at infinity. The first forms of l_1 and l_2 show that they each pass through the point T in which the tangent to the circle ABC at A meets BC. The second form shown that l_1 and l_2 are parallel respectively to the internal and external bisectors of the angle A.

The tangents to S at the points in which it is met by l_1 and l_2 are the common tangents of S and S′.

The line l_2 will always meet the circle S in real points; the line l_1 will meet it in real points if $a^2 > 4bc$.

If two chords of a circle are at right angles, the tangents at their extremities form a cyclic quadrilateral; hence since l_1 and l_2 are at right angles to each other, it follows that the common tangents to S and S′ form a cyclic quadrilateral which is real if $a^2 > 4bc$.

If $a^2 = 4bc$, the parabola S′ and the circle S touch each other, the line l_1 being the tangent at the point of contact.

The equations of the four common tangents of S and S′ are

$$[a\,(a^2 - 4bc)\,\mathrm{S} + bc\,l_1^2]\ [a\,(a^2 + 4bc)\,\mathrm{S} + bc\,l_2^2] = o.$$

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AUTHORS OF PAPERS.

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PROCEEDINGS

OF THE

NEW ZEALAND INSTITUTE

1910

PART I

EDITED AND PUBLISHED UNDER THE AUTHORITY OF THE BOARD OF GOVERNORS OF THE INSTITUTE

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PROCEEDINGS

OF THE

NEW ZEALAND INSTITUTE.

1910.

PART I.

WELLINGTON PHILOSOPHICAL SOCIETY.

FIRST MEETING: *4th May, 1910.*

Mr. A. Hamilton, President, in the chair.

New Members.—Miss Helyer, Mr. J. Marchbanks, Mr. F. C. Hay, Mr. J. D. Climie, Mr. M. N. Watt, and Mr. C. G. G. Berry.

Honorary Life Member.—On the motion of Professor Easterfield, seconded by the President, the following resolution was carried unanimously: "That this Society desires to place on record its appreciation of the valuable services of Mr. Thomas King during the term of his Secretaryship of the Society, by electing him an honorary life member of the Society."

The President announced that the Philosophical Institute of Canterbury had offered to supply members of the Society with copies of its publication "The Subantarctic Islands of New Zealand" at a reduced price.

The President referred to the loss sustained by the Society owing to the death of two of its members, Mr. A. P. Buller and Mr. G. R. Marriner.

Address.—The President delivered the following address:—

The Tararuas.—When I addressed you last year at this time I suggested that we should endeavour to open up the southern end of the Tararuas by cutting a track on the Quoin and establishing some kind of a camp there of a permanent nature. Early in the season, through the active co-operation of some of the members, a tent was erected in a suitable place just at the edge of a small piece of bush on the Quoin, and during the season it has been found useful as a shelter for several parties of explorers. Mr. Aston, who takes the greatest practical interest in this matter, has ascended several times, and has reported to me from time to time the condition of the track. Towards the end of the summer Mr. W. H.

Field, member of Parliament for Otaki, accompanied Mr. Aston to Mount Hector from the Kaitoke end, and came out at Otaki. I wished him to have a look at the Kaitoke end with a view to our co-operating with him in his efforts to cut a good track from the Otaki side, for which purpose a sum has been voted by the Government. I believe that the Lands Department has now agreed to undertake the expenditure of this £50 on the track from the Otaki Gorge through the bush at that end up to the clear land on Mount Denham. There is also a bridge being placed across the creek at that end. I hope that during the present season we shall be able to complete arrangements for working on our end of the track in the way of clearing the present track, so that horses may be taken up with provisions or materials for erecting a permanent hut. There are also some small difficulties about the approach to the track which I hope will be got over shortly, and I think that this year the Society might vote a small sum towards the expense of clearing the approaches. In my last address I suggested that we should endeavour to have a permanent hut erected on Ruapehu and another on the Tararuas. Since then I visited Ruapehu from Rangitaua, and I am of the opinion that there is no necessity for us to take the initiative in building a hut on that side of the mountain: the people in the locality have taken the matter up with so much vigour that in a short time I think every necessary facility will be provided for. At present there is very little difficulty in riding to within a short distance of the summit. This leaves us to devote our energies to co-operating with those who are working on the Tararua tracks from the Otaki side, and also with those who are working with a similar track from Masterton and the Wairarapa. It therefore appears that next summer we may be able to say that the Tararua Range is open to the study of naturalists to a better degree than it has ever been.

The results of the small amount of collecting on the Quoin and the adjacent parts show that there is a vast amount of material of a most interesting character ready to our hand. The collectors who have been there have been well rewarded in obtaining new species of insects and new records for many *Lepidoptera*. The alpine insects are so very local that as each fresh region of the alpine country is examined we may expect fresh discoveries and additions to our fauna and flora.

In one of Mr. Aston's papers which will appear in the forthcoming volume of the Transactions there is a useful map, unfortunately on a small scale, prepared by the Lands Department, showing the tracks upon the different spurs.

Mountain Observatories.—Before leaving this subject I may say that I should like to see later on a small observatory built on Mount Hector at which self-recording instruments could be installed for the purpose of making records during the winter-time, mainly of the rainfall and barometric pressure. The amount of alpine rainfall is not sufficiently estimated in this country, as a rule. Owing to the destruction of the bush on the lower grounds which retarded the descent of the water from the higher portions of the watersheds, the rainfall now descends very rapidly, and in consequence is liable to injure the valuable land on the flat, to say nothing of the culverts, bridges, roads, &c. I saw a suggestion the other day that observations of this kind should be taken on Mount Egmont, as there were facilities for doing so at the present time at the mountain houses. This should certainly be arranged, and observations taken at the head-waters of all the larger streams with a view to getting a better understanding of the water-power which will be valuable for industrial purposes when the question of the harnessing of rivers for electrical purposes is in a more practical position. This question of an accurate knowledge of the condition and amount of rainfall over given areas is perhaps even more important to those in manufacturing localities than a knowledge of the local weather is to the agriculturists and others who are concerned in the ripening and preservation of their crops. If electrical energy is provided for industrial purposes by water-power, we must have the knowledge of the probable rainfall, as well as the means of conserving and properly distributing the supply of water for the energy required.

Comet.—Perhaps I may be permitted to make one or two remarks on the subject of the comet, about which you will hear more this evening, which may interest, and which I think are hardly likely to be made by any of the gentlemen who are speaking on this subject. This brilliant visitor, known as Halley's Comet, is generally regarded as one which has made many brilliant visits at various dates, and the visit of 1066 is recorded in the Saxon chronicle in the following terms: "There was seen over all England such a sign in the heavens as no man ever before saw. Some men said that it was the star Cometa, which some men called the haired star; and it first appeared on the eve of Litania major, the viiith of the Kal. of May [24th April], and so shone all the seven nights." This was regarded after the event as William's lucky star.

"Ordericus Vitalis" (Book v, chap. ix) contains the following lines in reference to this comet:

> History's ancient annals fix
> The year one thousand sixty-six:
> Then a fiery comet whirled
> Dreadful omen, round the world,
> As the time when England's lord
> Fell before the Norman's sword
> —FORESTER.

Henry of Huntingdon, in concluding his account of William the Conqueror's reign, writes,—

> What though, like Cæsar, nature failed
> To give thy brow its fairest grace!
> Thy bright career a comet hailed,
> And with its lustre wreathes thy face.
> —FORESTER.

On one of the first coins struck by William I there appears a star, and authorities consider it possible that this star was a representation of the visit of this comet, and was adopted as a distinguishing mark for that issue of the coinage.

Chatham Islands.—I still hope that we may be able to organize an expedition for the purpose of studying the natural history of the Chatham Islands. At the time when I first brought this before you we were unable to get the co-operation of the other scientists in New Zealand, mainly because they were engaged in working up the material which they had accumulated in the visit to the Auckland and Campbell Islands; and you will no doubt have seen the two volumes which have been issued by the Philosophical Institute of Canterbury containing an account of the expedition and the scientific results. We must all join in the congratulations which have been offered to the editor, authors, and printer on the satisfactory result of their labours. I hope it will not be long before we shall have a volume of the same character on the Chatham Islands.

Library.—And now a few words with regard to a matter which requires attention in the affairs of the Society itself. We have in this room a very considerable number of books, and we subscribe as a Society to about twenty periodicals, and I think we should take steps to make provision for the proper binding of the numbers as soon as the year is complete. I think we have not expended any money in this direction for some considerable time. A year or two ago I was fortunate enough to get some binding done by the Government in the library in general, and possibly some of these periodicals may have been bound at that time; but it would be better if there were some general instructions to the effect that a certain amount of money should be expended on binding in each year. You may recollect that last year I drew your attention to a scheme which I had under discussion for the purpose of making the libraries of the branch Institutes available to students. There has been a good deal of correspondence on the matter, and there are some points still to be decided upon: but one of the main objects of the scheme has been attained, and it is now possible for any member of this Society to borrow from any of the other libraries, if they happen to possess it, any book that is not in this library that may be required by the member for the purpose of scientific research. This arrangement is, of course, subject to certain restrictions which are absolutely necessary, and which no reasonable person would dream of objecting to. The other main point which has not yet been settled is the question of a joint card catalogue. This entails preparation by an expert, and should be as far as possible uniform. The question of the cost has not yet been settled, and I am trying to find the cheapest and best way out of the difficulty. This catalogue should be compiled on the same basis by all libraries, and, although this may appear to be a simple matter, it has its difficulties. It is only, however, when this catalogue is satisfactorily made that we can proceed to consider the question of how far we can effect economies in the purchase of books. This is not, apparently, a burning question at the present time, as I find that the expenditure on books is not very great, the average number of new volumes added being small. I am more than ever convinced of the necessity for some united action, and more particularly with regard to scientific journals. I am frequently asked for the loan of volumes containing papers of importance in the leading periodicals; but in many cases we do not possess a complete set. This is to be regretted, as, though the libraries housed in this room have had exceptional opportunities during the last forty years, members have been unable to utilize their privileges to the best advantage, there being no regularly trained librarian, the care of the books having to be undertaken by the Museum officials. It is time that this was brought to an end if the library is to fulfil its functions properly.

Hector Fund.—You will be pleased to hear that the fund for the memorial to the late Sir James Hector has now reached a sum which will enable some practical benefit to accrue from it to science. The deliberations of the committee who have charge of the fund have not yet been announced, but before the next annual meeting I trust that a satisfactory scheme for the utilization of the fund will be before you. There are few members of this Society, however, who knew the late Sir James who will need any public memorial to strengthen in their hearts the memory of the many kindnesses they received from him, and to perpetuate the memory of a true friend to all scientists.

Obituary.—I may perhaps add my tribute of regret that the Society has lost within the last few months two scientists who loved their country and who enjoyed working in the fields of science. I refer to the death of the late Mr. A. P. Buller, who for many years studied with loving care the New Zealand *Lepidoptera*, and to the late Mr. G. R. Marriner, Curator of the Wanganui Museum, who was a well-trained observer in natural history, and whose death at an early age is much regretted by me. A very distinguished contributor to our Transactions, and a worker on New Zealand *Hemiptera*, has recently passed away in the person of Mr. G. W. Kirkaldy, entomologist to the Hawaiian Sugar-planters' Association. Mr. Kirkaldy was the recognized expert in *Hemiptera*, and was preparing to devote special attention to those species of *Hemiptera* which are injurious to vegetation in New Zealand. His services in *Hemiptera* were invaluable to sugar-planters, and his general scientific work was recognized throughout the scientific world as of the highest importance and interest.

New Zealand Palaeontology.—In the last volume of the Transactions I brought together a few notes relating to the present position of New Zealand palaeontology, and added a short bibliography of the literature on palaeontology of New Zealand. By the last mail a very valuable compilation was received from Professor Otto Wilckens, which brought together in an elaborate form the whole of the references relating to the geology of New Zealand in its widest terms. This publication will be invaluable to future workers, and we are indebted to Professor Wilckens for his labours in this respect.

While speaking to you about the suggested expedition to the Chatham Islands for the purpose of working up the natural history I should have mentioned that it might be possible to induce the Marine Department to so order the goings of the training cruiser, the "Amokura," that she should make soundings between New Zealand and the Chatham Islands. This would be useful, and would not interfere with the routine of the ordinary cruising voyages. I should be glad ~~if it~~ is found possible to make arrangements for such soundings.

I have purposely made my address to-night very short, as we have several gentlemen who have undertaken to speak on the subject which is of special interest at the present time—the reappearance of Halley's Comet. I will therefore commend to your thoughts and studies during the coming session the thousand aspects of the world around you, and if you can aid in the search for a fuller knowledge of things material and immaterial you will do at least a part of your duty. We are gradually recognizing that modern science and modern inventions tend to increase the community of material interests, and that many of our older ideas must be thrown overboard. Our isolation is gradually disappearing under the development of electricity, aviation, and other modern marvels, and we are pressing on to a fuller future, and gradually recognizing that in becoming enlightened the world rises to unity; that, instead of racial hatred and jealousy, we are progressing towards a time which will unite in one great Fatherland all the fatherlands we now pride ourselves in belonging to. We must, as Lamartine says, work for the time when we can call ourselves "fellow-citizens of every thinking soul."

Papers.—Halley and Halley's Comet: (1) Historical, by Mr. Thomas King; (2) Physical, by Rev. Dr. Kennedy, F.R.A.S.

Mr. Thomas King gave an historical address, in which he said that the interest in the comet did not lie in its brightness, its size, or its physical nature, but in the human associations that its very name suggested. The name of Halley was associated not only with the comet, but with the greatest scientific discovery the world had known, for without Halley the "Principia" of Newton would not have been published.

The Rev. Dr. Kennedy dealt with the physical properties of comets. Their movements could now be determined with accuracy, but there were still problems

regarding their constitution and structure upon some of which it was hoped light would be thrown by improved methods and appliances. The spectroscope had revealed hydrogen and hydrocarbons in the tails of comets. But the comets, though of large volume, were insignificant in mass. Bulking sometimes hundreds of times as large as the sun, they contained less substance than an asteroid ten miles in diameter. Their tenuity was almost inconceivable—a state of rarefaction exceeding the most perfect vacuum that could be produced artificially. Comets possessed a light of their own beside that reflected from the sun. but its nature was not yet determined

Both papers were fully illustrated with lantern-slides, including a fine series of photographs of the approaching comet taken at the Meeanee Observatory, Napier

Special Meeting: *30th May, 1910*

Mr. A. Hamilton, President, in the chair.

Paper.—"The Astronomical Importance of the Theory of the Third Body," by Professor A. W. Bickerton.

The author delivered a lecture on the astronomical importance of the theory of the third body before a largely attended meeting of the Society, and lucidly explained the formation of a third body from the partial collision of two celestial bodies. He said astronomers were now all agreed in recognizing the existence of "dead suns," and grazing-collisions among the stars, but were not in agreement as to the dynamic and physical changes produced by such collisions. The common assumption was that the two bodies concerned were enormously increased in temperature by collision; he held, on the contrary, that they were heated only to a comparatively slight extent, but that the third body, struck off in the collision, was heated to an enormous temperature. This third body had many times the energy of any other equal mass, and was capable of producing very extraordinary phenomena. Astronomers had missed the idea of the third body, as no reference could be found to it in any standard astronomical work, so that the idea had not presented itself to them sufficiently for them to speak about it. The lecturer entered minutely into the vast energies involved, and defined a new term necessary for any easy understanding of the forces involved—"kinetol," this being proportional to the reciprocal of the atomic weight: thus the kinetols of hydrogen and oxygen are as 16 : 1. The lecturer had taken up the problems more than thirty years ago, not as an astronomer or astrophysicist, but as an engineer with a knowledge of thermodynamics.* He had stated his problems and worked out their solutions, placing his results before astronomers for examination in the light of actual research. He found that the great works on astronomy contained many facts that could only, in his opinion, be explained by his theory; this was notably the case in spectrum analysis.

Mr. A. C. Gifford moved a vote of thanks to Professor Bickerton, and instanced various phenomena which were still a puzzle to astronomers and which this theory seemed to explain.

Dr. Kennedy, F.R.A.S., who seconded the motion, was unable to follow the theory in all points, yet recognized that Professor Bickerton had devised an admirable working theory, worthy of being put to the test by astronomers and investigators into astrophysics. The lecturer had been too modest to mention one important fact—his anticipations had been proved in the recorded spectrum of Nova Aurigae, which agreed with predictions made thirteen years previously. The theory deserved much more attention from leading astronomers than it had received in the past.

The President said he would be very pleased if the Society could help to bring the theory prominently before the astronomical world, and a recommendation might be made to the New Zealand Institute to help the matter forward.

The vote of thanks was carried amid hearty applause.

* See Trans. N.Z. Inst., 1878, 1879, 1880.

Astronomical Society.—Advantage was taken by the President of the large attendance of those interested in astronomy to introduce the question of the formation of an Astronomical Society or an Astronomical Section of the Society.

Dr. C. Monro Hector thought it matter for regret that the Carter bequest for a telescope had lain idle so long. He had no definite proposal to make, but thought the time opportune to bring the matter forward and try to interest the public in the subject.

Mr. C. P. Powles thought the time for action had come, and moved, That steps be taken to form a branch of the British Astronomical Association in connection with the Wellington Philosophical Society.

The motion, after some discussion, was withdrawn, it being uncertain whether a branch of the Association could be affiliated with the Society, and finally a committee was appointed to consider the whole matter and report to a later meeting, the committee to consist of Mr. A. Hamilton, Mr. C. E. Adams, F.R.A.S., Dr. Kennedy, F.R.A.S., Dr. Hector, Mr. E. D. Bell, Mr. G. V. Hudson, Mr. A. C. Gifford, Professor Easterfield, and Mr. C. P. Powles (convener).

Second Meeting: *1st June, 1910.*

Mr. A. Hamilton, President, in the chair.

New Members.—Mr. W. H. Carter, jun., and Mr. A. E. Aston.

Papers.—1. "The Elementary Psychology of Child-life," by Miss C. E. Kirk.

The author illustrated her paper by many personal experiences with children of different ages, and endeavoured to trace the causes of many interesting actions and sayings incidental to childhood.

2. "The Customs and Traditions of the Poutini Ngai-Tahu," by Mr. H. D. Skinner.

Abstract.

It should first be explained that the Ngai-Tahu were the tribe that claimed lordship over the greater part of the South Island at the beginning of the nineteenth century. The Poutini Ngai-Tahu were that branch of the tribe that had won a home in what is now called Westland. The succession of conquest in that district is as follows: First came Ngati-Waiiangi; they are said to have intermarried with or been conquered by Ngati-Mamoe, who were in turn conquered by Ngai-Tahu. Ngai-Tahu settled among the conquered, and the name Poutini Ngai-Tahu was given to the united tribe. In the years 1828 and 1832 these people were raided by bands from Ati-Awa and Taranaki, who, however, did not settle in the district, but withdrew.

Hardly any record of the customs and traditions of Poutini Ngai-Tahu has been preserved. For this reason it is worth recording details which if told of any other tribe might be called trivial. The Maoris from whom most of the information was obtained were,—Hemi, aged about 95; Mrs. Hemi, aged about 97; Kere, aged about 75; Jacob, aged about 65; and Bill, aged about 50. They were living at the Makawhio River, in South Westland, and belonged to Poutini Ngai-Tahu, though they probably had Ngati-Wairangi and Ngati-Mamoe blood in their veins.

The paper begins with an account of the various passes across the Southern Alps. It tells which of them were known to the Maoris, and to what extent they were used. It then describes in some detail the preparation of food, sandals, socks, and all the other things necessary for a journey across the range. Next comes some account of old-time hunting and fishing, after which journeys and routes from place to place on the West Coast are touched on. The account given of canoes

and canoeing is of greater general interest, so may be quoted in full. You will see that it throws light on the construction of double canoes—a point about which there is no information elsewhere—and that it raises the question of the existence of rowing, as distinct from paddling, among the Maori. It may well be the case that in this remote part of New Zealand old customs, long discarded by all other tribes, lingered on almost into our own time.

The natives said that the only voyage of any length ever made by the Poutini Ngai-Tahu was that from Bruce Bay to Milford Sound for *tangiwai*. Such a voyage would be made only once in a generation. It would occupy any length of time from a week to a month, as they landed at the slightest sign of bad weather. Katau said they travelled in winter; but that can hardly be correct. Natives of other parts of New Zealand sometimes came round the coast in canoes. It would thus seem that Poutini Ngai-Tahu were a timid folk—a supposition which is borne out by the history of their wars.

They made their canoes in their own district, two canoes of, say, 30 ft. and 20 ft. length by 4 ft. beam often being lashed together by cross-pieces. A canoe which Kere helped to make near Martin's Bay was called Kai-Whiri. The Arahura natives had come down for *tangiwai*, and the Bruce Bay Maoris took them and their *tangiwai* back in this canoe. There were five oars on each side. On being cross-questioned they asserted that they used oars sometimes, and sails of woven flax, before the white man came. If this statement as to rowing is true, the objects figured in Hamilton's "Maori Art" and in Hawksworth's illustrations of Cook's Voyage are probably oars.

Kere said that the ancient unit of measurement was the fathom, which was calculated by the span of a man's outstretched arms. He described the longer single canoe of the double canoe as being seven fathoms long. The shorter one would then measure five fathoms. Spars were lashed from each end of the longer to the corresponding ends of the shorter canoe. A platform united them about the middle. This was floored, and a mast was erected on it. They said that a big canoe from the North Island was washed up at Hunt's Bay. Though it was much battered, they could see by the braces and lashings that it had formed part of a double canoe. Two double canoes loaded with greenstone once went from Milford to Waimate. One of them was made on the Makawhio above Ritchie's by Tuarohi, "our grandfather." Two other canoes are mentioned as having gone to Kaiapohia.

Takahe (Notornis), *Moa* (Dinornis), *and Pou-a-Hawaiki.*

It is said that the Maoris hunted and caught the *Notornis* at the head-waters of the Rakaia, and that the last of them were seen there. When questioned on this point the natives could give no reply. They said that the takahe was large enough to kick the dogs. It was caught with a forked stick, with which its legs were pinned to the ground. It was not 10 ft. high, as the questioner suggested, for then, said Jacob, it would have been large enough to kick a man—it would, in fact, be a moa.

Although split and charred moa-bones have been found in the middens on the West Coast, the natives could tell nothing about the bird. They had, however, a story about a great bird which they called Pouahawaiki. This may have been the bird known to other Maoris as Pouaki. "Pouahawaiki" may perhaps be an expansion of "Pouaki," arising from a mistake as to its derivation. "Pou-a-Hawaiki" means "Pou from Hawaiki." Now, it will be remembered that a mythological character named Pou journeyed to New Zealand from Hawaiki on the back of a great bird. A confusion may thus have arisen between the two stories. But, whatever the derivation of the name may be, I have little doubt that the story is an old one, and has at least a kernel of truth, and that referring to the great eagle (*Harpagornis*), bones of which are to be seen in the Dominion Museum.

The natives said that once, a long time ago, some of the Maoris who went hunting or fishing failed to come home. Then, when their fellow-tribesmen watched, they saw an immense bird take up a man and carry him away to a hill-top. A Maori named Pukirehu fastened a dog's skin on a stick near a lagoon, and lay beside it in the water with only his head above the surface. He had armed himself with a long spear. The Pouahawaiki flew towards the skin, but when it saw Pukirehu's head it swooped down and attacked him with its wings. Then 'Rehu drove his spear hard at its wing. Again it came at him, and this time he made

a mighty thrust into its body, and it fell dead in the water. Then its mate flew down, only to be killed in the same way. Now Pukirehu climbed up to the eyrie, where he found the bones of many men who had been killed by the Pouahawaiki. He also found and killed two chicks, one of which was just ready to fly.

Dogs.

They said that the Maoris brought dogs with them when they came from Hawaiki. The descendants of some of these ran wild in the bush. Some of the domestic ones were kept for food and some for hunting. Their myth as to the creation of the first dog somewhat resembles Kipling's story "How the Elephant got his Trunk": Two brothers once went out hunting. One of them went down on his hands and knees to allow his brother to comb his hair. Then his brother made him stay down, and pulled his nose till it grew long like a dog's nose, and his ears till they became like a dog's ears. So he went on, till the man became a dog and ate dirt. When they went home their father said, "Where is your brother?" The son said, "Here he is," and whistled, and the dog ran up. This is a debased form of the story of Irawaru given to Wohlers by the Ngai-Tahu of Ruapuke Island.

War.

The Poutini Ngai-Tahu were not a fighting race. Excepting the fights against *tauas* from the North Island which invaded the Poutini coast in the years 1828 and 1836, their only regular warfare consisted in border skirmishes with Ngati tu-mata-kokiri to the north of them. When defeated, they scattered into the bush. It is said that the natives of Greymouth retreated by canoe up the Grey and the Arnold into Lake Brunner. This was denied by those interrogated. The idea of keeping the existence of the passes secret for strategic reasons had not occurred to them. The paths of the *tauas* were the ordinary trade-routes.

Greenstone.

The paper next deals with the working, cutting, and marketing of greenstone, after which it treats of mythology and traditions. It is interesting to find a branch of the Maori race shut off for so many centuries from the northern tribes telling exactly the same story of the coming of the Tainui and Arawa canoes as is told by the tribes of the North Island. The incidents are those of the well-known story, though the names of the canoes are not given. They had, as was natural, an intimate knowledge of the story of Tama-Ahua, discoverer of the greenstone. The most interesting variation from the published version was supplied by Jacob, who said that Tama-Ahua blew the dart, putting his hand to his mouth to illustrate. There are in the MS. fragments of other legends of which fuller versions have been printed; and there are indications of legends that now never can be told. At the present day time would only be wasted in regrets.

One tale which was given in fuller detail than in any published version is the well-known one of Raureka. Raureka was the mad woman of the Ngati-Wairangi Tribe who, about the year 1700, discovered Browning's Pass, and, pushing on across it, descended the eastern slopes of the Alps. Following down the course of a stream, she came on a party of Ngai-Tahu shaping a canoe somewhere near the present site of Geraldine. Seeing, perhaps, that she was mad, they did not interfere with her. She watched their cutting, which was slow, for their adzes were made of *toki uri*, or basalt. Taking from her bundle a little packet, she showed them what all versions of the story agree in calling the first piece of greenstone the eastern tribes had seen. Now, we know well from archaeological research, as well as from other traditions, that greenstone was known to Maoris in all parts of New Zealand long before the time of Raureka, and this contradiction has caused historians a good deal of trouble. Stack, in his "History of the South Island Maoris," has no satisfying solution to offer, and Mr. Justice Chapman, in what will probably long remain the classic essay on the working of greenstone, leaves the question open. The true explanation of the story as we now have it seems to be that in the course of generations the emphasis has been moved on to the wrong point of the story. The story did, as might be guessed from its persistence, enshrine an event of the greatest importance. That event was not the discovery of the greenstone, but the discovery of a new and easy road to it. Before Raureka's lifetime, doubtless, greenstone ornaments and weapons had been rare. Parties in search of the stone had been faced either by a canoe voyage along a stretch of rugged and storm-beaten coast, or by a long and difficult journey on foot around the coast from Arapaoa to the Arahura. The boldest might well be

daunted by either course. But now a pass had been discovered across the mountain barrier, and the way was easy. At once, we are told, a war-party gathered, crossed the pass, fought with Ngati-Wairangi, and came home laden with the stone.

If this interpretation of the story is the true one, all the other passes known to the Maoris must have been discovered since the journey of Raureka.

3. "Halley's Comet," by Mr. C. E Adams, M.Sc., F.R.A.S.

The author exhibited a number of large-scale diagrams showing the path of Halley's Comet, with positions every ten years since the 1833 apparition, the positions being obtained by the graphical solution of Kepler's problem, using the method devised by the late J. C. Adams; while other diagrams showed the relative positions of the Earth, Venus, and the comet in 1835 and 1910. Appreciative reference was made to the excellent results of Messrs. Cowell and Crommelin's predicted return of the comet, their date of perihelion passage being 1910, April 16·57 G.M.T., while the actual date was very close to April 19·7. The difference, about three days, would require a correction of about 130,000 miles in the semi-major axis of the ellipse, a quantity of the same order of magnitude as the uncertainty of the Earth's distance from the Sun. The author gave a brief account of the photographs of the Sun taken every five minutes from 2 to 3 p.m. on the 19th May, but stated that no certain trace of the transit of the comet could be seen

Exhibits.—1. Mr. H. D. Skinner exhibited a Maori paddle, probably used by the Ngai-Tahu.

2. The President exhibited an ancient Maori musical instrument, about 18 in. long, and elaborately carved, and resembling a flageolet. It probably came from the Bay of Plenty, and was procured by Major Robley.

AUCKLAND INSTITUTE.

FIRST MEETING: *17th May, 1910.*

Dr. R. Briffault, President, in the chair.

New Members.—A. Buchanan, A. W. Chatfield, J. Coe, A. B. Harding, R. Cranwell, Hallyburton Johnstone, W. Satchell, Rev. W. Trotter, R. M. Wilson.

Professor H. W. Segar, M.A., delivered a lecture on "Halley's Comet."

After describing the general features of comets, and the views held by astronomers respecting them, the lecturer gave a full account of the previous visits of Halley's Comet. He then described Halley's great discovery of 1705, in which, as the result of calculation and observation, he predicted that the comet was periodic, and followed a regular orbit contained within the limits of the solar system. In this Halley made one of the first applications of the knowledge given to the world in Newton's "Principia." The peculiarities of the orbit of Halley's Comet, as compared with those of other comets, were then dealt with, and the path followed by it during its present visit was described, its position at various times being compared with that of the Earth. The lecture was copiously illustrated with limelight views and diagrams.

As the hall proved much too small to accommodate the audience, the lecture was repeated, with slight alterations, on the 23rd May.

SECOND MEETING: *6th June, 1910.*

Dr. R. Briffault, President, in the chair.

New Member.—R. J. Morgan.

The President delivered the anniversary address, taking as his subject "The Nature of Life."

The lecturer explained the mechanical theory of life, and contrasted it with the old theory of vitalism. The latter was, he said, inconsistent with the principle of the conservation of energy, and of the equivalence of forces. It was noteworthy, nevertheless, that in many quarters dissatisfaction had of late been expressed with the mechanical theory, and that many biologists displayed a tendency to return to vitalism in some modified form. Among the causes of this tendency were the fact that the mechanical theory did not supply an interpretation of the distinction between living and non-living matter, and that the ideal of the theory—the reduction of living processes to terms of physics and chemistry—had not in any instance been achieved. The mechanical theory originally regarded life as the property of a chemical compound, protoplasm. That view, however, was negatived by the fact that perpetual change of chemical composition is a

sine qua non condition of life. The study of metabolic processes had recently made great advances, which were discussed at some length, and the lecturer concluded that nothing exactly analogous to the process was known in the inorganic world. Metabolism, which might be a manifestation, or cause, or result of unknown physical conditions, was, the lecturer submitted, the proximate known physical basis of vital processes.

Passing to a discussion of the reactions of living objects, the distinctive characters of those reactions appeared to be a continual self-adjustment, and re-adjustment to external conditions—in other words, adaptability. The analogy between automatic devices designed to meet a certain purpose, and adaptive response to all conditions, with continual readjustment, was, the lecturer said, superficial and misleading.

Since the physical conditions of the metabolizing organism differed in a fundamental manner from any to be found in non-living objects, it was not surprising that the principle of the self-adjusting mechanism could not be deduced from inorganic phenomena. And, since the readjustment was known in some cases to be accompanied by sensibility, it was not unreasonable to suppose that the physical phenomena corresponding to sensibility constituted that self-adjusting mechanism which is distinctive of living organization.

Third Meeting: *4th July, 1910.*

Dr. R. Briffault, President, in the chair.

Mr. S. E. Lamb, B.Sc., delivered a popular lecture on "Ferro-concrete Structures," illustrated with numerous lantern views. At the close a discussion arose, in which the President, Mr. Moore, and Mr. W. E. Bush took part..

MANAWATU PHILOSOPHICAL SOCIETY.

FIRST MEETING: *17th March, 1910.*

The President, Mr. W. F. Durward, in the chair.

New Members.—Messrs. G. H. Bennett, J. Mounsey, C. N. Taplin.

Papers.—1. "The New Zealand Saddleback," by W. W. Smith, F.E.S.

2. "The Ancient Maori, and some of his Peculiarities," by D Sinclair, C.E.

The Secretary reported that since the last meeting between forty and fifty fresh exhibits had been received at the Museum, and that the need of increased accommodation was becoming daily more urgent, as it was impossible under present conditions to make use of the Museum for educational purposes.

SECOND MEETING: *21st April, 1910.*

The President, Mr. W. F. Durward, in the chair.

The Hon. Dr. Findlay, K.C., gave a lecture on "Legal Liberty."

The lecturer described the evolution of government in England, and the various influences at work, attributing the theories ultimately adopted to the French dreamer Rousseau's philosophy of government as embodied in "Le Contrat Social," published in 1762, that were adopted in the French Revolution, and have replaced the teachings of John Stuart Mill in England.

The lecturer summarized his conclusions thus: There is in Anglo-Saxon nations an excessive impatience of State interference, due partly to the struggle by which freedom has in the past been wrested from Government. That in their attitude towards the powers of the State the people of our nation are apt to ignore the fact that it is only from these powers and under their protection alone that they derive their rights and liberties. For many centuries man has been trying to find some scientific boundary between the rights of the individual and those of the State; and the theories of Hobbes, Locke, Rousseau, and Adam Smith resulted in the doctrines of natural liberty which limit the State's functions to those of keeping order and protecting rights, while they extend the area of individual freedom to the widest extent possible without injury to the rights of others. This led to a fanatical individualism, under which the condition of the English labourer was worse than at any previous period of English history. The school of natural liberty still largely dominates orthodox economic thought. It is based upon the cosmic process, the struggle for existence and the survival of the fittest, and is opposed to the moral or ethical process of human betterment. Thought and experience has shown that in modern nations the system of natural liberty is not a policy of true social progress; that, on the contrary, such progress can be attained only by limiting greatly individual liberty and by eliminating the struggle for a bare existence. That the true policy of progress in modern nations is not the mere protection by the State of legal rights, but provision by the State of the conditions which are essentials to the welfare of the people. That for the improvement of those coerced, and for the provision of the conditions of general welfare, the State may, in defiance of the tenets of individualism, properly curtail individual liberty. That, as the solidarity of a nation increases and society becomes increasingly organized, the closer relation and interdependence of the units of population necessitate a restricted area of individual freedom. That conceptions of the area of personal freedom have changed with changes in our national aims, and a policy of "Want and Vice and their Reduction" is slowly supplanting the cardinal policy "Wealth and its Production." That the trend of the freest democracies is towards a State paternalism. That the national character and temper of our nation may be trusted to prevent any serious limitation of the area of liberty really essential to a self-respecting vigorous manhood.

At the close of the lecture the chairman spoke eulogistically upon it, and so did Mr. E. D. Hoben, who moved a vote of thanks on behalf of the Society, and Mr. D. Buick, M.P., who seconded it.

OTAGO INSTITUTE.

First Meeting: *3rd May, 1910.*

The President, Professor Waters, in the chair.

The President delivered his presidential address, entitled "Mining Education in relation to the Mining Industry."

The President referred in feeling terms to the serious illness of the Vice-President, Dr. Hocken, and commented on the very great interest which Dr. Hocken had always taken in the Otago Institute, and he moved a hearty vote of thanks to him for the gift of some valuable periodicals which he had recently presented to the Institute. This was carried with hearty applause.

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Second Meeting: *7th June, 1910.*

The President, Professor Waters, in the chair.

The President announced certain changes which had taken place in the *personnel* of the Council, Dr. Fitchett having been elected in the place of Dr. Malcolm (resigned), Mr. Alexander Bathgate having been elected Vice-President in place of Dr. Hocken (deceased), and Mr. E. J. Parr in place of Mr. Bathgate.

New Members.—Messrs. R. W. Brickell, Cuthbert Fenwick, Charles Butterworth, W. T. Glasgow, George Howes, and J. C. McGeorge.

The President referred to the inestimable loss sustained by the Institute through the death of Dr. Hocken, and on the motion of Dr. Colquhoun the following resolution was carried in silence, the members standing:—

That the members of the Otago Institute record their keen sense of loss at the removal by death of Dr. T. M. Hocken, who has been a member since the inception of the Institute in 1869. During these forty-one years Dr. Hocken was a member of the executive for thirty-seven years, and held the position of President on three occasions. As a member he was most enthusiastic, and ever ready to contribute to the proceedings. Whilst taking a keen interest in all subjects brought before the Institute, and in its aims and objects, he devoted himself to investigating and recording the early history of New Zealand. Endowed with a temperament favourable to close study, and possessed with perseverance, his investigations in this his labour of love remain as an undoubted authentic record for all times in his volumes entitled "Contributions to the Early History of New Zealand," and "Bibliography of New Zealand Literature." He has by his priceless gift to New Zealand of all the documentary and other evidence upon which his records are based enhanced the value of these records beyond estimation. This evidence, now forming portion of the Hocken collection, housed in the Hocken wing of the Otago Museum, will ever be a history of the Dominion defined and traced from the earliest beginnings. This Institute joins in the hope that his collection, freely given, will ever be under good guardianship, and expresses its appreciation of his high ideal of citizenship and his fine personality, which endeared him to all who knew him

Dr. Benham showed some very interesting and valuable mats of Maori workmanship. These mats had been presented by the late Dr. Hocken, and some of them were of historical value. They were of different kinds, were used for various ceremonies and different occasions, and each had its own special Maori name. He also showed a very valuable tattooed dried Maori head from Dr. Hocken's collection.

Mr. George Howes exhibited some specimens of moths and butterflies.

Dr. Marshall gave an address upon the geology of the Cook and Society Islands, and made interesting references to the features he had observed during a trip to the Islands. He dealt with the theories advanced by Darwin, Sir John Murray, and Professor Agassiz as to the formation of the coral reefs around the Islands, and said that his own observations supported Darwin's theory. Dr. Marshall, with the assistance of Dr. Benham, showed a number of photographic views of the Islands, which he commented upon and explained in a very lucid manner.

THIRD MEETING: *5th July, 1910.*

The President, Professor Waters, in the chair.

New Member.—Mr. Peter Barr.

Papers.—1. "Description of an Undescribed Barnacle of the Genus *Scalpellum* from New Zealand," by Dr. Annandale, Superintendent of the Indian Museum, Calcutta; communicated by Dr. Benham.

2. "The Occurrence of the Starfish *Nectria* in New Zealand," by W. B. Benham, F.R.S.

3. "Note on a Male Coccid (*Leachia zealandica* Maskell), by W. B. Benham, F.R.S.

Dr. Pickerill showed the tooth of a deer which was supposed to have a coating of gold upon its grinding surfaces. He then read an interesting paper entitled "Golden Teeth."

Dr. Pickerill pointed out that, though cases of alleged golden teeth had occurred from time to time in human beings and various lower animals, when the matter came to be carefully investigated it was evident that the golden sheen or fluorescence upon the teeth was really due to the presence of an organism which had the power of giving a greenish-golden tint to any substance on which it was growing. It is probable that a thin deposit of calculus on the teeth was thus coloured, giving them a peculiarly golden appearance.

Dr. Benham exhibited the decorated skull of an Andaman-Islander, which was a most interesting relic of mourning worn by the widow on various occasions. The skull was curiously marked with circular patches of colour, decorated with shells, and was worn suspended from the back of the head. Dr. Benham also showed a human lower jaw from the Andaman Islands, which was similarly worn by relatives of a deceased native, as a mark of mourning or respect. These interesting exhibits had been presented by Captain Malcolm Thomson, M.B., late of the Indian Medical Service.

Dr. Fulton then read a paper giving a description of a visit to Rio de Janeiro in 1889.

Dr. Fulton pointed out the very unhealthy condition of the city at that date, yellow fever being very prevalent. He described many prominent features of the city, its magnificent harbour, the interior of the Cathedral, the Jardin Botanique, the Corcovado Railway, and, after giving a few statistics of modern Rio, showed how, under improved conditions of sanitation, destruction of the mosquito-larva, establishment of electric tramways and lighting, the city had become one of the finest and most up to date of the New World. In concluding the lecturer showed some fine photographs of Rio and suburbs, which were kindly exhibited by means of the lantern by Dr. Benham.

PHILOSOPHICAL INSTITUTE OF CANTERBURY.

SPECIAL MEETING: *20th April, 1910.*

Present: Mr. R. M. Laing (President), in the chair, and eighty others.

The President explained that the meeting had been called to give members an opportunity of hearing a paper by Professor Bickerton on a vital point of his theory, and to allow of full discussion thereon. He gave a brief historical account of Professor Bickerton's efforts to lay his theory before the scientific world, and a summary of its leading features, and said that if it were true it would establish a new cosmogony.

Professor Bickerton then read the paper, entitled "Recent Evidence in favour of the Existence of the Third Body."

The paper was criticized by Drs. Farr and Evans, and by Mr. E. G. Hogg, who drew attention to the discrepancies between the recent spectroscopic observations and the predictions made by Professor Bickerton as deduced from his theory.

Professor Bickerton replied as occasion demanded.

At the conclusion of the discussion a hearty vote of thanks was accorded to Professor Bickerton for his paper.

FIRST MEETING: *4th May, 1910.*

Present: Mr. R. M. Laing (President), in the chair, and eighty-five others.

New Members.—Miss Cocks, Captain A. A. Dorrien-Smith, D.S.O., Messrs. M. C. Gudex, W. G. Aldridge, D. B. McLeod, E. J. Haynes, H. Vickerman, W. F. Robinson, H. D. M. Haszard, Langford P. Symes, Dr. H. G. Denham, Rev. J. T. Pinfold, and the Hon. H. F. Wigram.

"*Subantarctic Islands of New Zealand.*"—A copy of the recently issued work on the subantarctic islands was laid on the table, and several appreciative letters were received in connection with its appearance. The hon. editor, Dr. Charles Chilton, was presented on behalf of the contributors with a bound copy of the work containing their autographs, and a letter congratulating him on the able way in which he had carried out the duties of editor of the volumes.

Address.—"The Nesting Habits of Fishes," by Mr. Edgar R. Waite, F.L.S., the retiring President.

The lecturer placed before the meeting some original observations on the nesting habits of fishes, and illustrated his address by lantern-slides of the various nests described and of their fabricators.

The evolution of the fish's nest was traced, from the mere disturbance of the gravel bed and the mounds of the lampreys, to the elaborate structures of the pihaya and sticklebacks, and it was mentioned that the filaments which bind together the materials of the nest of the latter fish were secreted from the kidneys of the male. The researches of Budgett and others into the nesting habits of

African fishes were mentioned, and the peculiar habits of *Aspredo* and other cat fishes, of the pipefishes and sea-horses, and the parasitical methods of the bitterling, were detailed. The remarkable bubble nests of the rainbow-fish and fighting-fish were described, and illustrated by photographs taken by the lecturer.

Some popular errors were indicated, including the widely advertised habit accredited to the Sargasso fish (*Pterophryne*), which was supposed to make the "nest" found in the gulf-weed. It has been known for some time that the eggs are those of a flying-fish, which by means of their filament hold the fronds of weed into a nestlike mass, but the old story still appear in quite recent fish literature. It was explained that the Sargasso fish really lays its eggs at the surface, and that they form an immense raft, like those of other members of the same family.

SECOND MEETING: *1st June 1910.*

Present: Mr. R. M. Laing (President), in the chair, and seventy-five others.

Obituary.—Resolutions of regret at the death of Dr. Hocken, Professor C. H. H. Cook, and Mr. G. W. Kirkaldy, of Honolulu, were carried.

New Members.—Miss Gertrude M. Bullen, Miss Hall, Dr. J. Guthrie, sen., and Messrs. T. Hughes and R. King were elected members.

Papers.—1. "Some Hydroids from the Kermadec Islands," by F. W. Hilgendorf, M.A., D.Sc.

ABSTRACT.

The hydroids were collected by Mr. W. R. B. Oliver in 1908, and all came from Sunday Island. They are all calyptoblasts, and are in most cases only skeletons. Nine species are represented in the collection, and of these one is also found in Australia and Europe; one in New Zealand, Australia, and Europe; one in New Zealand, Australia, and South Africa; one in New Zealand and Australia; three are also found in New Zealand; and two are probably not found elsewhere.

This list indicates the close relationship of the hydroid fauna with that of New Zealand, and this relationship is explained by the fact that hydroid-covered seaweeds are probably carried northwards from New Zealand, as are the kauri logs found cast ashore on Sunday Island. The two species not identified as having been previously recorded probably belong to the genus *Aglaophenia*, though in the absence of the reproductive structures they could not be determined. They are, however, described and figured. One of the species identified (*Aglaophenia laxa*) has apparently not been recorded since Allman found it in New Zealand thirty-six years ago. He did not find the *Corbulae*; these were present in the Kermadec specimens, and are described and figured.

2. "Notes on Reptiles and Mammals from the Kermadec Islands," by W. R. B. Oliver.

ABSTRACT.

The capture of a specimen of green turtle on Sunday Island is recorded. Some account is given of the habits of the humpback whales, which regularly visit the group, and of the Pacific rat, with special reference to the possible means by which the latter species may have reached the Kermadecs, evidence being adduced to show that Sunday Island was once inhabited by natives. Some notes on goats and cats recently introduced into the Kermadec Islands by man follow, and special attention is drawn to the fact that the cats prey chiefly on mutton-birds and terns, the former bird forming an important article of food for the inhabitants.

3. "Glacial Phenomena of the Upper Rakaia and Ashburton Valleys," by R. Speight, M.A., M.Sc., F.G.S.

The author exhibited a series of lantern-slides dealing with the locality and illustrating the effect of glaciation on the landscape. Attention was drawn to the fact that the Southern Alps in their present form are not a true mountain-range, but

a dissected plateau or peneplain, which has been formed from a previously existing range of the alpine type, the folding of which has not been acute. This was illustrated by pictures taken from the summits of mountains in the district. The effects of the former glaciation to which the area was subjected in Pleistocene and more recent times was then dealt with, special note being taken of the changes in drainage, the mode of truncation of spurs and dissection of the ridges between valleys, the formation of glacier pot-holes on a large scale, and the general smoothing and terracing action of glacier ice. The marked recent retreat of the glaciers of the region, notably the Cameron Glacier, was emphasized, also the fact that so few glaciers are forming terminal moraines at the present time, although they formed them in past times. A number of slides dealt with the Lyell and Ramsay Glaciers, at the head of the Rakaia River. This locality is almost unknown, and the author, with two student companions, was the first to ascend and note the features of the Lyell Glacier, although its terminal face had been previously visited and crossed by Mr. Roberts, the late Chief Surveyor of Westland. Two fine tributaries of the Lyell Glacier were named after Professor Heim, of Switzerland, and Dr. Cockayne. The last part of the paper, dealing with evidence for the change of climate which followed the glaciation of the area, was held over for reading and discussion at a future meeting.

Exhibit.—Mr. R. Nairn then exhibited a specimen of *Bilbergia zebrina* which showed the effect of moist conditions in a greenhouse on a plant which usually grows in arid country.

THIRD MEETING: *6th July, 1910.*

Present: Mr. R. M. Laing (President), in the chair, and over eighty others.

New Members.—Miss Margaret Richardson, Mr. W. B. North, and Drs. E. A. Washbourn and F. J. Borrie.

Paper.—"Additions to the Fish Fauna of New Zealand," by Edgar R. Waite, F.L.S. (see p. 25).

Address.—"The Permanent Pastures of New Zealand," by Mr. A. H. Cockayne, Government Biologist.

The lecturer said that in New Zealand, where the pastoral interest occupied the premier position, the grass crops were the most important asset. Of the 38,000,000 acres in occupation, grass lands claimed 36,000,000 acres, or 92 per cent. There could be added another 5 per cent. for those crops, such as turnips and rape, which supplemented the grass in times of scarcity. The grass crops were the backbone of the rural industry. In dealing with his subject, it was necessary to divide pastures into two sections—viz., permanent and temporary pastures. The permanent pastures were those which remained in a more or less stable condition for many years, and did not enter into any system of crop-rotation. Temporary pastures were those which occupied a most important part in reference to crop-rotation, and did not remain in a stable condition for any length of time. Of the 36,000,000 acres of grass land, 22,000,000 were still in their original condition. They had not been sown in any way, and a large percentage was occupied by the tussock region. There were 9,000,000 acres of grass land which had been formed from forests, and there were 5,000,000 acres which had been ploughed and sown, chiefly by machinery.

The lecturer then proceeded to show a number of lantern-slides showing the different kinds of pasture in various parts of New Zealand, and the methods of producing them. The series illustrating the transformation of rough forest land into fine pasture land, graced with a homestead, and flocks and herds, was a particularly informing and interesting one, the various stages from the "burn" to the final scene of pastoral perfection being capitally illustrated. A number of subsequent pictures showed the disastrous results which had followed overstocking and the injudicious burning of tussock. In these cases the land had become depleted, and its stock-carrying capacity reduced enormously. A painful illustration of the point

was provided by a number of views from the Clyde district in Central Otago, a view of the land being shown in its original state, with another view of it after its depletion. One fact was stated to show the effect on the pastoral industry. In 1890 there were 441,000 sheep in Vincent County; in 1910 there were only 277,000. If it were not for the wing thistle, erroneously called the "star" thistle, the land would lose still more of its carrying-capacity. Views were also shown of land in Canterbury which had suffered through the destruction of the tussock by injudicious burning. The lecturer said that the restocking of the land with grasses presented a very difficult problem, and it must necessarily be a slow process. He showed a number of views of American areas which exhibited the same depletion, and remarked that experiments for their restoration to usefulness had so far resulted in failure. The views of Australian and American pasture were interesting as affording comparisons with New Zealand, as well as by introducing to the audience the grasses most affected in those countries.

Mr. D. D. Macfarlane thanked the Institute for sending an invitation to the committee of the Agricultural and Pastoral Association to be present. They had listened to the address with very much interest. It was a fact that the carrying-capacity of runs in Canterbury was decreasing every year. That was partly due to continual burning, partly to overstocking, partly to rabbits and other causes. The chief cause, probably, was the insecurity of tenure. If a tenant had a secure tenure, and his improvements were conserved to him, he would see that his country was not destroyed. Every one knew it was necessary to do a certain amount of burning, but it should be done in the spring-time, and in sections which precluded the possibility of the fire spreading over the whole country.

Mr J. Stevenson also referred with appreciation to the lecture, and remarked that the views of the depletion of land in America and Central Otago should be a warning to pastoralists to do everything in their power to preserve their pasture lands.

There was some discussion as to whether the original pastoralists, before putting sheep among the tussocks, had had a "burn," but no definite information appeared to be available.

Mr M. Murphy, who briefly referred to the evils of overstocking and injudicious burning, proposed a vote of thanks to the lecturer, and this was carried unanimously.

This account is taken from the Christchurch *Press*, to which thanks are due.

HAWKE'S BAY PHILOSOPHICAL SOCIETY.

FIRST MEETING: *27th May, 1910.*

Present: The President (in the chair), and a large number of ladies and gentlemen.

New Members.—H. Hill, W. Fossey, and Dr. Simcox.

Lecture.—Dr. Henry gave a lecture on "Heredity and Disease." A brief discussion followed.

Prizes.—Prizes were offered to school-children for best collections of shells, insects, and plants.

Polynesian Society.—The Institute became a member of the Polynesian Society.

SECOND MEETING: *24th June, 1910.*

Present: The President (in the chair), and about fifty others.

New Members.—Rev. R. I. Coates, J. Fitzgerald, R. Grant, J. King, J. Snodgrass, and J. P. Thomson.

Papers.—1. "Tarawera and Rotomahana soon after the Eruption of 1886 and Twenty-three Years later," by Mr. H. Hill, B.A., F.G.S.

ABSTRACT.

In this paper the author compares the appearance of the Rotomahana district as known before the eruption and soon after the eruption, with the present appearance.

He visited the devastated area soon after the eruption, and, in company with Mr. Blythe, the officer in charge of road-construction, inspected the rift in Tarawera, the earthquake flats towards Pareheru and Tikitapu, the sites of Wairoa, Rotomahana, Waimangu to be, and the scarcely known Wai-o-tapu Valley, where they christened the Primrose Terrace. These are described, the desolate dull grey of the country, and the yawning, hissing, steaming abyss which took the place of the beautiful Rotomahana and its terraces, being then very impressive.

Stones, cinders, ashes, and sand came from the volcanoes, but only bluish-grey mud seems to have come from the Rotomahana crater.

Destructive effects seemed wanting to the south of the ridge separating the drainage-areas of Rotomahana and Wai-o-tapu, hardly any trace of eruption being noticeable in the latter place.

The country before the eruption was described by the Rev. Mr. Chapman ("Missionary Record," 1838); Dieffenbach (1841); Rev. W. Colenso ("Tasmanian Journal of Science," vol. i); Hochstetter (1859), whose map, published in 1863, is the only authoritative one of the pre-eruption time known to the writer; Domett (in "Ranolf and Amohia"), Trollope, and Froude.

Since the eruption Rotomahana increased from 25 acres in August, 1886, to 5,600 acres in 1893, and rose from a level of 565 ft. to 985 ft. It is now about 7,500 acres in extent. It seems to be fed by underground springs as well as by the ordinary drainage-water.

River-basin formation can be well studied in the district.

The country is now fairly well covered with vegetation, lichens, acacia (used here for firewood), grass, clover, fern, *Epilobium*, *Gaultheria*, *Veronica*, *Dracophyllum*, and tutu being mentioned as noticed.

2. "The Taupo Plateau," by Mr. H. Hill, B.A., F.G.S.

ABSTRACT.

This paper is an account of the formations met with between Napier and Taupo along the coach-road, and an explanation of the way in which the surface of Taupo district has been altered. Of two diagrams accompanying the paper, one shows the beds lying alongside the road, and the other Lake Taupo with its more important geological features.

Starting from near Napier, the appearances of limestone, conglomerate, shingle, sand, fossiliferous sand, and pumice are noted. Titiokura Hill is of Miocene beds. At Taurangakuma are Maitai slates, and thence to Tarawera slates and sandstones prevail, intrusive volcanic rocks appearing near Tarawera; beyond are rhyolites. Sandstones of Otumakioi are similar to the Permian of England. Piki-o-kiko-wera is of volcanic rocks.

On from Rununga are lavas and pumice terraces. Volcanic mounds and crateral lakes are noticeable. The Rangitaiki River rises in such lakes. Trachytes appear, and sandstones top the low hills at the north of the Kaimanawa Mountains. Peat lignites, 9 ft. thick, are exposed in the Rangitaiki bed, and these are overlaid with pumice. The country here seems to have been covered by a series of lakes. Down the river are remnants of an immense crater.

Thirteen miles from Taupo is a ridge which seems the eastern side of a great Taupo crater.

The alteration in the drainage-areas of Taupo district and of Hawke's Bay by the eruptions of Taupo, Rotokawa, and Pihanga volcanoes is explained. The effects of earthquake-action round Taupo are discussed, and Maori lengends are quoted to support the views put forth.

The Institute expressed its sense of the services rendered by Mr. Hill in past years, and wished him a pleasant time during his coming visit to England.

ABSTRACTS.

1. Additions to the Fish Fauna of New Zealand, by Edgar R. Waite, F.L.S., Curator, Canterbury Museum

The following are among the more noteworthy species taken in 1907 by the Government trawling expedition, additional to those previously enumerated. Fuller descriptions and figures will be published later.

Chlorophthalmus nigripinnis Gunther.

This species was freely taken on two occasions in the Bay of Plenty, and is an addition to the known fauna. The only species of the genus hitherto recognized from New Zealand is *C. gracilis* Gunther, but it was not obtained by the expedition.

Macrorhamphosus scolopax Linnaeus.

Not having European examples for direct comparison, I provisionally associate with this species examples netted in the Bay of Plenty. The snipe-fish was but once taken, seventeen examples being secured; great numbers escaped through the large meshes of the trawl net as it was being hauled to the surface, and the majority of those preserved were skimmed off the surface of the water with a hand-net. The genus was previously unknown in the waters of the Dominion.

Syngnathus norae sp. nov.

D., 39; P., 13; C., 8; rings, 18 + 49 = 67.

Length of head 7·4 in the total, 2·6 in head and body, height 2·8 in the same; eye, 7·0; snout, 1·7 in the head. The dorsal begins on the 17th ring, and stands on ten rings. The brood-pouch occupies twelve rings, and measures 5·1 in the tail.

The head is low, being but half the depth of the body; the snout is long, more than twice the post-orbital length of the head; the dorsal begins on the anterior of the two rings occupied by the vent, and its base is not elevated; the opercle is not crossed by a ridge.

Colour green with brown cross bands, five semi-bands on the body; the three middle bands, each of which occupies three rings, have, above the lateral ridge of the body, a brown vertical mark on each of the contributing rings; there are eight complete bands across the tail; a brown line from the eye to the snout, on each side.

The nearest ally of *S. norae* appears to be *S. semistriatus* Kaup, the markings being described thus: "Under the interrupted lateral line, 19 cross stripes; above that line, yellow spots with black borders." In the New Zealand species the body-bands are confined to the upper half of the side. Length, 221 mm.

Netted from Stewart Island northward to Pegasus Bay; also obtained from the stomachs of *Callorhynchus* and *Polyprion*.

Zanclistius elevatus Ramsay and Ogilby.

A single example of this fish was taken in the Bay of Plenty, and constitutes an addition to the known fauna of New Zealand.

Macullochia gen. nom. nov.

In 1872 Castelnau used the name *Richardsonia* generically for *Histiopterus labiosus* Gunther, but in 1903 I drew attention to the fact that it had been first applied by Steindachner in 1866 in the *Atherinidae*. I did not, however, move further in the matter. Since that time Dr. Jordan has reviewed the Histiopterid fishes of Japan, and has supplied a key to all the genera of the family. He appears to have overlooked my former note, for he still uses the name *Richardsonia* as

applied by Castelnau. Mr. A R. McCulloch, whose name I associate with the species, informs me that he has received a large number of specimens, which enable him to pronounce *H. farnelli* as the young of *M. labiosa*, notwithstanding the differences exhibited by the type specimen.

Cepola aotea sp. nov.

D., 74; A., 69; V., i, 5; P., 20; C., 6 + 4.

Length of head, 9·8; height of body, 12·6 in the length; diameter of eye, 3·0; interorbital width, 6·0; and length of snout, 5·1 in the head.

The preopercle is unarmed, and the maxilla extends to below the middle of the eye. The lower jaw protrudes and fits into a notch in the upper one, the anterior teeth remaining without when the mouth is closed; the teeth in the jaws are in single series, but there is a patch in front of the lower jaw, the anterior teeth of which are strongly curved; there are no teeth on the vomer, palatines, or tongue. The dorsal fin arises above the edge of the opercle, the anal less than the length of the head behind it.

The scales are extremely small; no colour remains after the partial digestion of the fish, but there is a conspicuous black spot on the membrane between the maxilla and premaxilla; no mark traceable on the dorsal fin.

The largest specimen was taken from the stomach of a *Zeus*; smaller ones were obtained from *Pagrosomus*; all being taken in the Bay of Plenty.

The genus is new to the waters of the Dominion, and the species is typically a *Cepola* as restricted by Bleeker. The Australian *C. australis* Ogilby differs in having a much smaller number of rays in the dorsal and anal, and also by the absence of the black spot noticed in other species. *C. aotea* may prove to be not distinct from *C. rubescens*, but, pending absolute comparison, may receive a distinctive name.

Pseudolabrus pittensis sp. nov.

D., ix, 11; A., iii, 10; V., i, 5; P., 13; C., 14 + 11; L. lat., 25; L. tr., 4 | 9.

Length of head, 2·7; height of body, 2·6; length of caudal, 3·4 in the total; diameter of eye, 7·0, interorbital space 4·0; and length of snout, 2·9 in the head.

Four series of scales on the cheek, no sheath at bases of vertical fins. Caudal subtruncate the depth of the peduncle, 1·9 in the length of the head.

General colour purplish, darker above, yellow beneath. Six dark bands on the body; they do not reach the lower edge; the first is close behind the head, the last on the caudal peduncle; these bands extend on to the membranes of the dorsal fin. The pectoral has a purple bar across its base, and the distal two-thirds of the ventrals are black. Length, 271 mm.

Caught with hand-line off Pitt Island, one of the Chatham Group.

Pterygotrigla Waite.

In diagnosing *Otohime*, a new genus of gurnards, Drs. Jordan and Starks contrast it with *Chelidonichthys*, but do not mention *Pterygotrigla*, which leads me to infer that they have overlooked the latter genus, of which *Otohime* appears to be a synonym.

Pterygotrigla has thus three species—namely, *P. polyommata* Richardson, *P. hemisticta* Jordan and Starks, and the following:—

Pterygotrigla andertoni sp. nov.

D., vii. 12; A., i. 11; V., i, 5; P., 11 + 3; C., 11 + 8; L. lat. 65, Vert. 10 + 16 = 26.

Length of head, 2·9; height of body, 3·8; length of caudal, 4·8 in the total; diameter of eye 3·2, interorbital space 3·0; and length of snout, 2·1 in the head.

Form and coloration much as in *Pterygotrigla hemisticta*, but maxilla does not extend beyond the anterior margin of the orbit. One large plate in front of the dorsal fin and five pairs of smaller ones bordering the spines. The rays are relatively higher and both pectoral and ventral are longer, while the chiropods (free pectoral rays) are shorter than in that species. The black spot on the dorsal fin of *P. hemisticta* is replaced with small scattered spots like those on the body; the rays bear three rows of spots, and the ventrals and chiropods are also spotted. The pectoral of *P. hemisticta* has two rows of milk-white spots, whereas in *P. andertoni* there are seven black bars.

Length 294 mm. Bay of Plenty; trawled by Mr. Thomas Anderton, of the Portobello Fish-hatchery, Port Chalmers.

2. **The Pharmacological Action of Tutu, the Toot-plant of New Zealand,** by Professor C. R. Marshall (Trans. Roy. Soc. of Edinburgh, vol. xlvii, 1910, pt. ii, No. 13, pp. 287–316, 9 figures). MS. received, 20th November, 1909: read, 21st June, 1909; issued separately, 29th January, 1910.

Professor Marshall has been working at the pharmacology of tutu during the last ten years, the pure tutin being supplied by Professor Easterfield and the abstractor. Being published after the researches of Dr. Fitchett and Professor Malcolm (Trans. N.Z. Inst., xli, p. 286), the author's paper will no doubt be read with considerable interest. Professor Marshall in a footnote states, in so far as the experiments are common with those of Fitchett and Malcolm the results are in general agreement; on a few physiological points only are the researches not in accord.

fessor Marshall thus summarises his results:—

1. Tutin, the active principle of the toot plant, causes epileptoid convulsions in various classes of animals. After large doses to rabbits the earliest convulsions commence with a general tonic spasm, which is followed by clonic movements. After small convulsant doses the convulsions begin with clonic spasms of the muscles of the head. These extend to the fore and then to the hind part of the body, and may terminate in a tonic spasm. The latter convulsions after larger doses also assume this form. After the initial convulsions following small doses, somersaulting movements are not uncommon.

2. The convulsions are mainly of cortical and pontine origin. Convulsive movements can be obtained when the brain is divided below the pons, but they are less characteristic and are more difficult to induce than when the pons is intact. In frogs the optic lobes seem to be the most important centres affected. Unequivocal conclusive movements were not obtained below a section of the spinal cord.

3. The convulsions arising in the pons are very susceptible to anaesthetics. This probably explains why convulsions are limited to one side after excision of one cerebral hemisphere during the continuance of the anaesthesia.

4. In unanaesthetized rabbits the two fore limbs act together, and the two hind limbs act in concert and synchronously during tutin convulsions; in the anaesthetized animal the limb-movements are often asynchronous. Individual muscles of the limbs often act vicariously, and this probably explains the irregular clonus which the movements of the limbs show.

5. Preceding the onset of the convulsions the medullary centres are stimulated. This effect is also produced by non-convulsant doses.

6. All doses which produce an obvious action cause in rabbits a fall of body-temperature.

7. When heated with dilute caustic-alkali solutions, tutin rapidly decomposes, the product being pharmacologically inactive. Prolonged heating with dilute acids leads to the same result.

8. The substance most closely allied to tutin—namely, coriamyrtin—is a more powerful convulsant, and, for similar physiological doses, is more rapid and more transient in action than tutin.

B. C. A.

3. **New Zealand Ctenophores.** "Raccolte planctoniche, fatte dalla R. nave 'Liguria'": vol. ii, *Ctenofori*, by Alessandro Ghigi, 1909.

In 1906 there was published (Trans. N.Z. Inst., xxxix, p. 138) an account of two species of Ctenophores from the New Zealand seas, the first to be recorded scientifically—viz., *Beroe shakespeari* and *Euplokamis australis*. Professor Ghigi now publishes a report on the representatives of this group collected during the cruise of the Italian warship "Liguria." The ship visited New Zealand in 1904, and amongst the new species recorded are two from our seas—viz., *Hormiphora labialis* and *Sabaudia liguriae*, the latter being the type and sole species of a new genus. The former was obtained between Norfolk Island and Auckland; the latter

between Cape Campbell and Lyttelton. Both of the new species are figured. Moreover, the species which I attributed to *Euplokamis* Professor Ghigi places with two others in a new genus *Moseria*. We now know four species of Ctenophores from our seas, the result of mere haphazard collecting: this suggests that with more systematic research many more species will be found. Our knowledge of these lower pelagic forms is very meagre. W. B. B.

4. New Zealand Petrels.

The fifth and concluding part of F. du Cane Godman's "Monograph of the Petrels" has now been received, and it perhaps would be well therefore to add to the extract from the book which I have already made relating to the New Zealand petrels,* for the information of workers in this country.

Prion brevirostris Gould (Short-billed Blue Petrel). Plate lxxxv.

"Gould's name for this *Prion* must be changed, as, although he quotes his description of *P. ariel* as occurring in a paper published in the 'Proceedings of the Zoological Society,' it is not to be found there, and it therefore becomes a *nomen nudum*. As Professor Reichenow points out, the bird must now be designated *P. brevirostris*. Although Sir Walter Buller separated the two forms under the names of *P. ariel* and *P. brevirostris*, I can see no difference between the type specimen of the latter from Madeira and the ordinary specimens from Australian seas usually called *P. ariel*."

Pelecanoides urinatrix Gm. (Diving Petrel). Plate lxxxvi.

This bird appears to be found in the southern part of South America. There is considerable variation in this species, and apparently there is a slight difference in the form found in Australia and the New Zealand form

Pelecanoides exsul Salvin (Kerguelen Diving Petrel). Plate lxxxvii.

Nestlings from the Chatham Islands are described.

Diomedea exulans Linn. (Wandering Albatros). Plate lxxxix.

A good summary of the history of this difficult species is given. It is our Antipodes Island bird, and its only known nesting-place is on that island.

Diomedia regia Buller (Royal Albatros). Plate xc.

The figure of both this and the previous species appear to me to be capable of improvement.

Diomedea melanophrys Boie (Black-eyebrowed Albatros). Plate xcvii.

This very widely-ranging species is well figured.

Diomedea bulleri Rothschild (Buller's Albatros). Plate xcviii.

The description and figure are taken from the type specimen in the Tring Museum obtained from the Snares.

Thalassogeron cautus Gould (Shy Mollymawk). Plate xcix.

Thalassogeron salvini Rothschild (Salvin's Albatros). Plate c.

Breeds on Bounty Island.

Thalassogeron culminatus Gould (Grey-headed Albatros). Plate ci.

Mainly in the seas to the south of New Zealand, although stragglers have been recorded from widely separated localities.

Thalassogeron chlororhynchus Gm. (Yellow-nosed Albatros). Plate cii.

The figure makes it easy to separate this from the preceding species.

* Proceedings N.Z. Inst., 1908-9, pt. ii, p. 61.

Phoebetria fuliginosa Gm. (Sooty Albatros). Plate ciii.

This species breeds on the Auckland and the Antipodes Islands

Phoebetria cornicoides Hutton (Hutton's Sooty Albatros).

The author erects this bird into a separate species, intending to consider it a variety of *fuliginosa*. It appears to have a more southern range than the darker form. The adult is described as being similar.

The whole work is provided with a sufficient index and a small list of errata and corrigenda. Mr. Godman in the preface to the whole work points out the difficulties he has been labouring under in completing the work begun by the late Mr. Salvin, and makes his acknowledgments to those who have helped to carry the work to a successful completion. Mr Keulemann's drawings have been coloured by Dr. Sharp's daughters. There is no doubt that this monograph will be of much use in the study of this admittedly difficult group. There is also an article by Mr. Pycraft on the systematic position of the petrels from their anatomical character. This is followed by a systematic list of the species and a classification of the group, with a key to the subfamilies and species.

A H

5. Globicephalus melas Traill.

An important paper on the osteology of the skull of *Globicephalus melas* Traill appears in the "Annuario del Museo Zoologico della R. Universita di Napoli" (nuova serie), vol. iii, No. 8, of the 21st October, 1909, relating to a specimen obtained from the Gulf of Salerno, where, however, it is of very rare occurrence. Three photographic views of the skull are given. The paper gives an interesting history of the species so far as relates to its occurrence in the Mediterranean. It occurs somewhat frequently on the coasts of New Zealand. The paper also contains a table and measurements, and a list of works cited

A H

6. Mesoplodon bowdoini Andrews.

In volume xxiv of the Bulletin of the American Museum of Natural History, published in 1908, there is an article, commencing on page 203, describing a new species of *Mesoplodon* from the Canterbury Province, New Zealand, by Roy C Andrews, with a plate (No. 12) and five text figures. This paper is descriptive of a skeleton collected at New Brighton Beach, Christchurch, in 1904, and now in the American Museum of Natural History. The species has been named *M. bowdoini* in honour of G. S. Bowdoin, one of the Trustees of the Museum. A full series of measurements are given, and illustrations of the most important parts of the anatomy. Unfortunately no comparisons are given with the known New Zealand species, but the measurements of *M. bidens* and the allied species *M. europaeus* are supplied. The skeleton is supposed to be that of an adult male.

A. H

7. New Zealand Lichens.

It may interest botanical workers in New Zealand to know that there is a good bibliography by Edwin Cheel of the literature on Australian and New Zealand lichens in the Journal of the Royal Society of New South Wales, vol. xl, 1906. The New Zealand portion is contained in the second paper, commencing at No. 146, on page 147, and runs up to No. 204, on page 151. The bibliography gives the papers on the lichens of the Chatham Islands and Campbell Island, and several other groups, such as Fiji, New Hebrides, Tonga, Samoa, &c. The first part, which is Australian, is in vol. xxxvii, pp. 171 82, 1903.

A H

8 Maori Numeration.

[The following proverbs which were intended to accompany the paper on 'Maori Numeration,' by Hare Hongi (Trans N Z Inst vol xlii p 625) were omitted owing to an oversight Ed]

Tutu te ngahuru, papaku mahuru or
Harvest time, piles (of food) spring time low stocks

Ngahuru kei runga, apu' nui kei raro or
(Sign of) tenth month above, of food abundance below

Ngahuru huna kai, huna tangata or
Harvest time wealth of foods consequently of mankind

Ngahuru tomo te kai, tomo te tangata or
Harvest month great in foods, great in mankind

Ironical references to those who avoided the labours of tillage

Ka ti koanga, whakapiri ngahuru or
Absent at digging time, present at harvest time

Koanga tangata tahi, ngahuru puta noa or
At digging time a single friend, at harvest time surrounded

He ngahuru, he moe or
At harvest time prayers (are heard for a share of one's crops)

Ngahuru kai hanga, koanga kai aro ke or
At harvest time (you) face one board, at tillage time (you) face another's board

John Mackay, Government Printer, Wellington—1910
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PROCEEDINGS

NEW ZEALAND INSTITUTE

1910

PART II

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PROCEEDINGS

OF THE

NEW ZEALAND INSTITUTE.

1910.

PART II.

WELLINGTON PHILOSOPHICAL SOCIETY.

THIRD MEETING: *6th July, 1910.*

Mr. A. Hamilton, President, in the chair.

New Member.—Mr. E. S. Baldwin.

Astronomical Section.—The President referred to the report of the committee on the proposed formation of an Astronomical Section, and announced that owing to lack of time the Council was not prepared to recommend any proposal at present, but that a conference between the Council and the committee would take place at an early date.

Mr. C. P. Powles, chairman of the committee, expressed disappointment that the Council had not had time to reach a conclusion, and hoped the intended conference would be held shortly for the purpose of putting something definite before the public.

Papers.—1. "Notes and Descriptions of New Zealand *Lepidoptera*," by Mr. E. Meyrick, B.A., F.R.S., F.Z.S.; communicated by Mr. G. V. Hudson.

2. "A Revision of the Classification of the New Zealand *Tortricina*," by Mr. E. Meyrick, B.A., F.R.S., F.Z.S.; communicated by Mr. G. V. Hudson.

3. "Notes on the Life-history of *Melanchra rhodopleura* and *Leucania epiastra* Meyrick," by Mr. R. M. Sunley.

4. "New Zealand *Lepidoptera*: Notes on Collections made in 1909–10," by Mr. H. Hamilton, A.O.S.M.; communicated by Mr. A. Hamilton.

Exhibits.—The President exhibited interesting entomological specimens recently added to the Museum; also some stone implements recently received from India.

The President announced that the sum of £10 had been voted to Professor Bickerton to assist him in the elaboration and publication of

his astronomical theory; but the Council, in wishing him every success in his efforts to obtain a full hearing for his theory, does not profess to form an opinion as to its merits, but wishes him to have every facility in presenting it to the astronomical societies for criticism.

Joint Library Scheme.—The Chairman announced that the Council had resolved to allow Victoria College students and others interested the privilege of consulting books in the library, under suitable regulations to be drawn up by the Council.

FOURTH MEETING: *3rd August, 1910.*

Mr. Thomas King, Vice-President, in the chair.

Astronomical Section.—The report of the committee set up to advise on the formation of an Astronomical Section was received, and contained the following resolutions of the committee:—

1. That an Astronomical Section of the Wellington Philosophical Society be formed.
2. That the objects of the section be the establishment of an observatory in or about Wellington, and the promotion of the study of astronomical subjects generally.
3. That a fund be established for promoting the objects of the Carter bequest, and for rendering it available as soon as possible.
4. That the proposed observatory, if established, be called the King Edward VII Memorial Observatory, as a memorial to the late King.
5. That the question of promoting such a memorial be brought before the public, and that for this purpose a committee be formed, including prominent citizens, in conjunction with members of the Philosophical Society.

On the motion of Professor Easterfield, seconded by Mr. G. V. Hudson, it was resolved, That an Astronomical Section of the Wellington Philosophical Society be formed.

On the motion of Mr. G. Hogben, seconded by Professor Picken, it was resolved, That the Secretary should call a meeting of all who desire to form the section, and that the new section be forthwith formed, and elect its own officers.

Papers.—1. "University Reform," by Professor T. H. Laby.

2. "The Need for a Society of Eugenics in New Zealand," by Professor H. B. Kirk.

[Reports of these papers, and of the discussion thereon, were published in the *New Zealand Times* of the 4th and 6th August.]

SPECIAL MEETING: *17th August, 1910.*

Mr. Thomas King, Vice-President, in the chair.

An apology was received from Mr. A. Hamilton, President, for non-attendance, on account of ill health.

Mr. T. Buckley, Chief Electrician of the Telegraph Department, delivered an interesting lecture on wireless telegraphy, illustrated by numerous diagrams and experiments. The lecturer reviewed briefly the history of "wireless," and described the existing systems in considerable detail, and gave a number of practical illustrations on the apparatus

erected in the lecture-room. The lecture was listened to with close attention, and on its conclusion the Chairman moved a hearty vote of thanks to Mr. Buckley for his interesting and instructive lecture

Special Meeting: *22nd August, 1910.*

Mr. A. Hamilton, President, in the chair.

Astronomical Section.—This meeting was held in accordance with the resolutions carried at the meeting held on the 3rd August to form an Astronomical Section of the society.

The Secretary read the resolutions relating to the section.

The President briefly explained the objects of the section, which he declared duly formed He then left the chair, and the section met to elect its officers, &c.

Fifth Meeting: *7th September, 1910.*

Mr. A. Hamilton, President, in the chair.

The Chairman referred sympathetically to the loss the society had sustained in the death of Mr. George Denton, a very old member of the society, and of Mr. Alexander Shand; and, on the motion of Mr. King, it was resolved that votes of sympathy and condolence should be communicated to their relatives.

Mr. H. L. James was prevented by indisposition from attending the meeting, and apologized for being unable to deliver his address on "Othello."

Papers.—1. Professor Kirk opened the adjourned discussion on his paper on the need for a Society of Eugenics in New Zealand, and briefly repeated the arguments in favour of the establishment of such a society.

Mr. G. V. Hudson, in supporting Professor Kirk, made a strong plea for the study of the science of heredity in our educational institutions.

2. "Notes on the Discovery of *Dactylanthus Taylori*," by Mr. James Grant, B.A.; communicated by Mr. T. W. Downes. In the absence of Mr. Downes, this paper was read by the Chairman.

3. "Preliminary Note on the Fungi of the New Zealand Epiphytic Orchids," by Mr. T. L. Lancaster; communicated by Professor Kirk. On the invitation of the Chairman, Mr. Lancaster read his paper.

Exhibits.—1. Mr. M. Crompton Smith exhibited a helio-chronometer, or universal sun-dial, and stated that trials carried out by himself showed that the instrument will give the time correct within a minute or less, and that not only can local mean time be obtained, but that the instrument will also give standard time as well as local, and standard time for any other place to which it is set.

2. The Chairman exhibited an ancient stone bowl from the east coast; a carved stone from Rabbit Island, Nelson, probably used as a kanaka god; and an *onewa*, or blackstone *mere*.

3. Mr. G. V. Hudson exhibited some excellent enlarged photographs of insects, by Mr. Davies, Greytown.

AUCKLAND INSTITUTE.

FOURTH MEETING: *1st August, 1910.*

Dr. R. Briffault, President, in the chair.

Lecture.—Mr. A. Wyllie, Electrical Engineer to the City of Auckland, delivered a lecture on "Wireless Telephony."

The lecturer explained the different systems at present in use, taking first of all those dependent on light or heat radiation, such as the photophone, the speaking arc, the photographophone, &c. He then passed on to consider those modes which are worked by means of electrical forces, explaining at some length closed-circuit telephony, electro-magnetic induction telephony, and spark telephony.

A large number of illustrative experiments accompanied the lecture, and the "speaking arc" was exhibited for the first time in Auckland. A unanimous vote of thanks was awarded to Mr. Wyllie.

FIFTH MEETING: *29th August, 1910.*

Dr. R. Briffault, President, in the chair.

New Members.—A. Allison, J. C. Dickinson, W. Cole, F. Finch, G. Graham, D. Holderness, T. Macfarlane, J. E. Moore, Hon. J. McGowan, A. H. V. Morgan, E. K. Mulgan.

Lecture.—Mr. E. V. Miller delivered a lecture on "The Ultra-microscope."

The lecturer pointed out that the magnitude of an object which can be rendered visible by the highest power of the microscope is now well understood, and that from the very nature of light we cannot hope for much further improvement. Those objects which are too small to be revealed by the ordinary microscope are consequently called "ultramicroscopic," and require special modes of treatment to make their presence appreciable. There are two methods at present in existence, which may be called respectively that of ultra-violet light and that of diffraction on a dark field. The lecturer showed that by modification of these two systems it is possible to render visible infinitely smaller things than can be exhibited by the finest microscope, and that even the almost inconceivably small particles suspended in a colloidal solution can be seen, measured, and their movements observed.

SIXTH MEETING: *26th September, 1910.*

Dr. R. Briffault, President, in the chair.

New Members.—E. A. Price, J. W. Stewart, R. Leslie Stewart, J. Wilson.

Lecture.—The Rev. Archdeacon Walsh gave a lecture on "The Effects of the Disappearance of the New Zealand Bush."

The lecturer sketched the causes of the destruction of the forests—cattle, fire, and the axe of the bushman. Cattle roam through the bush and destroy the undergrowth, and fire follows immediately afterwards. The consequences of this deforestation are great and far-reaching, and are of two kinds, climatic and topographical.

Dealing with the climatic changes, Archdeacon Walsh said that after two or three fires had passed over an area of land it left the soil very poor and scantily protected with vegetation. It became easily heated by the sun, and then the air was heated by radiation from the earth, giving rise to winds which parched up surrounding lands, prematurely ripened crops, and rendered other areas liable to be swept by fire. When the forests were near the sea, their destruction left the way open for sea-winds, which carried salt spray many miles inland, and killed still more vegetation. In northern Taranaki and at Hokianga it had been found that severe frosts, hitherto unknown, had followed deforestation, owing to the loss of protection from cold winds from the sea. Although in many districts every possible acre was being cleared in order to allow for the grazing of dairy cattle, it would have been better had a reasonable amount of bush been left standing as protection.

As for topographical results, when heavy rain fell on forest land most of it was held by the trees and evaporated again. When the bush disappeared the water began to flow on the surface, causing erosion and landslips. This erosion gradually filled the water of the rivers with solid matter, which was deposited on the bottom, raising the bed until the river overflowed, and destroyed wide tracts of land by silting and by eating out other courses, and eventually caused the formation of harbour bars.

In many countries foresting work was carried out to a large extent, but the methods generally adopted were not at all applicable to the New Zealand bush. It was impossible to thin New Zealand forests. Once this work were started, fire must follow, and the bush be totally destroyed. And no amount of reafforestation could make up for the damage which had already been done.

Looking into the future, one could only see the damage already done being greatly increased. Reafforestation was being carried on in a way by the Government, but not at all in proportion to the area which had been wasted. There was no hope that forests at present standing would remain intact. Land must be found for settlers, and as long as there was a demand for timber the sawmiller would be found to attack the bush. Even the present Government reserves were not safe, and would not be until they were surrounded by stout barbed-wire fences, for, once cattle and pigs got into the bush, fire was a natural consequence. Several reserves have already been lost in this way.

Settlers in different parts should be made to keep certain areas always under timber. Thus they would have adequate protection for their remaining lands, while at the same time they would find that they had no more profitable crop than their timber-trees.

Seventh Meeting: *24th October, 1910.*

Dr. R. Briffault, President, in the chair.

Lecture. The Rev. D. D. Scott delivered a lecture entitled "Huxley: an Appreciation and a Criticism."

The lecturer emphasized the human qualities of Professor Huxley: he was neither icy nor remote. With a towering intellectuality, he had a childlike and loving personality, and a warm home-life. His early struggles no doubt toughened him for his future work, and he lived through his trials to see the fruit of his labours. Huxley's great services in support of the theory of evolution were dwelt upon, and then the lecturer entered upon the critical side, pointing out certain inconsistencies in his logic, and particularly in what may be called his school of philosophy. The lecture concluded with a warm tribute to Huxley's rare independence of character and transparent integrity.

MANAWATU PHILOSOPHICAL SOCIETY.

THIRD MEETING: *5th September, 1910.*

The President, Mr. W. F. Durward, in the chair.

New Members.—Messrs. C. R. Hewett, R. McNab.

Paper.—Mr. E. D. Hoben read a paper on "The Moving Picture," and its various historic, scientific, business, and educational aspects, showing the immense possibilities of the machine as it was developing—how it would presently show scenes in natural colours and with all the sounds produced simultaneously.

After the paper various questions were asked, especially in relation to the method of production of trick films, and attention was called to a remarkable film recently exhibited at the Empire Hall, in which a second picture is shown within the covers of a book, apparently quite independent of the main movement.

Alteration of Rule.—On the motion of Captain Hewitt, acting for Mr. Eliott, seconded by Mr. Hoben, Rule 3 was altered to read as follows: "Candidates may be elected members of the society, on the recommendation of a member of the Council and of one other ordinary member, by a majority of the Council present at any meeting of the Council, and on payment of the annual subscription within three months."

FOURTH MEETING: *20th October, 1910.*

The President, Mr. W. F. Durward, in the chair.

Additions to the Museum.—Some recent additions to the Museum were exhibited, including the collection of ferns exhibited by Mr. Lancaster at the last Winter Show of the local Agricultural and Pastoral Association, to which had been awarded the society's prize; also a collection of fossils from Scinde Island, and a couple of *meres* and some Maori ornaments, which were described by Mr. C. M. Waldegrave, the owner, one of the *meres* having belonged to Te Rauparaha.

Paper.—Mr. R. McNab then read a most interesting paper on "Recent Researches into the History of Te Rauparaha's Raid on Akaroa, and the French Race for the same Place in 1840," showing with regard to the latter event, from original documents, both French and English, that the generally accepted story was quite unsupported by facts.

OTAGO INSTITUTE.

FOURTH MEETING: *2nd August, 1910.*

The President, Professor Waters, in the chair.

There were forty members present.

New Members.—Messrs. E. E. Stark, James Nicoll, and R. A. Farquharson.

Papers.—1. Professor Waters laid on the table an important contribution by Mr. R. A. Farquharson, M.A., entitled "The Occurrence of Platinum in New Zealand," and he proceeded to show by means of maps and diagrams the various localities where the metal is obtained, and how by different methods the pure metal is finally extracted. He spoke in highly flattering terms of the work that was being done by Mr. Farquharson.

2. Mr. J. Crosby Smith sent in a paper on the plants of Lake Hauroko, and this was read by the Secretary.

Exhibits.—Mr. George Howes exhibited some fine specimens of *Lepidoptera*, and Dr. Benham spoke of the valuable work that was being done in the field by Mr. Howes.

Address.—Dr. Fulton gave a short address entitled "An Hour with a Water Diviner," and argued that in the man interviewed there was no more than a shrewd knowledge of localities, a good idea of the run of all the streams in the district worked upon, and an almost imperceptible voluntary contraction of the muscles of the fingers, which caused the twig to descend wherever it was deemed expedient.

Dr. Benham and Mr. McLeod also spoke on the subject.

FIFTH MEETING: *6th September, 1910.*

The President, Professor Waters, in the chair.

There was a large number of members and friends present.

Address.—Dr. Cockayne, of Christchurch, gave a most interesting address, entitled "The Scientific Importance of our Scenic Reserves and National Parks."

The lecturer stated that New Zealand stood out pre-eminently among the countries of the world in the care taken for providing that certain natural objects and natural phenomena shall remain the heritage of the people for ever. There were 414 scenic reserves, several vast areas known as national parks, and a number of islands known as sanctuaries.

By means of lantern-slides the lecturer kept his audience closely interested, showing totaras, kauris, mosses, and ferns, and explained the anatomy of forest leaves and the peculiar variation of alpine plants, and commented upon the adaptability of plants to their surroundings. He showed the effect of wandering dunes upon the surrounding plant-life, and also how wind can affect the nature of forest growth.

On the motion of Dr. Benham, a hearty vote of thanks was accorded to the lecturer.

SIXTH MEETING: *4th October, 1910.*

The President, Professor Waters, in the chair.

There were twenty members present.

New Member.—Mr. Roger Buddle.

Exhibits.—Dr. Benham exhibited,—

(1.) A widow's cap, made of seaweed, worn by a Maori widow during her period of mourning.

(2.) A widow's cap from Australia. This was made of white clay, and was a very ponderous and uncomfortable article of head-wear.

(3.) A money-girdle from Santa Cruz. This was some 30 ft. or 40 ft. in length, and its construction was most interesting, as it was formed on one side by millions of real feathers carefully and neatly inserted and interlaced with the fibrous materials of the belt.

(4.) A curious sleeping-coverlet from the Solomon Islands. This was made from palm-leaves sewn in parallel lines.

(5.) Some Australian weapons with flint heads.

(6.) A fish-hook from New Guinea. This was similar in construction and ornamentation to our New Zealand fish-hooks.

(7.) Some very quaint and grotesque masks from New Guinea.

(8.) A finely constructed basket from one of the South Sea islands.

Mr. George Howes showed,—

(1.) Some fine Australian *Lepidoptera*, several of them closely allied to our local species, also some highly coloured and very beautiful species from South America.

(2.) A number of complete specimens of the vegetable caterpillar, and also several pieces of caterpillars that had been cut to pieces while digging. Since the exhibitor had got them, each piece had thrown out its shoot or spore-bearing portion; and he asked for an explanation of this hitherto-unrecorded fact.

Dr. Benham, in giving a short account of the life-history of *Porina*, stated that the fungus sends out fructifying shoots in the line of least resistance—in the living animal, generally just behind the head.

Professor Marshall showed some alkaline rocks from Tahiti, and discussed the question of a great continental area in the Pacific.

Professor Waters showed some fine specimens of gold-ore, and delivered an interesting sketch of the gold currency of the world. He showed the following exhibits:

(1.) Banket ore from South Africa, 800 ft. level.
(2.) Ore from the Queen of Sheba Mine, South Africa.
(3.) Sulphide ore from Waihi, 500 ft. level.
(4.) Oxide ore from Waihi, higher level.
(5.) Reefton gold from the Inkerman Mine.
(6.) New chum gold, or mica schist, from the Shotover Valley.
(7.) Shotover Valley quartz, with gold.

Papers. Professor Park laid on the table the following papers:—

(1.) "The Glacial Moraines of Marlborough and South Nelson," by Professor James Park.

(2.) "The Coalfields of West Nelson," by J. Henderson, D.Sc.; communicated by Professor Park.

(3.) "A New Fossil *Mactra* from the Pliocene Beds at Mataroa and Turanga-a rere," by Henry Suter; communicated by Professor Park.

(4.) "A New Fossil *Turritella* from the Upper Cretaceous Beds at Brighton and Kaitangata," by Henry Suter; communicated by Professor Park.

(5.) "On the Expansion and Contraction of Glacier Ice due to Varying Temperatures," by Professor James Park.

(6.) "On the Development of the Land Features of West Nelson," by J. Henderson, D.Sc.; communicated by Professor Park.

PHILOSOPHICAL INSTITUTE OF CANTERBURY.

FIFTH MEETING: *3rd August, 1910.*

Present: Mr. R. M. Laing (President), in the chair, and seventy others.

New Members.—Messrs. J. A. Bartrum and W. L. Parker.

Address.—"The Geology of the Cook and Society Islands," by Dr. P. Marshall.

The lecturer gave a very lucid and interesting description of the geology of the islands, based on observations made during a recent visit. He dealt specially with the characteristics of the coral reefs surrounding the groups, and illustrated his remarks with a very fine series of lantern-slides, some of which were made from photographs taken by the lecturer himself during his visit. Some of these were taken from the mountains overlooking the reefs, and displayed in a striking and original way their position and extent, a feature which photographs taken from near sea-level fail to illustrate. Dr. Marshall referred to the various theories of the origin of reefs, and to the geological structure of the islands which they encircle. The Cook and Society Islands consist largely of alkaline volcanic rocks, and their occurrence here runs counter to a widely accepted theory which associates such rocks with coast-lines of the Atlantic type.

At the conclusion a very hearty vote of thanks was accorded to Dr. Marshall for his address, and for the time and trouble he had spent in coming from Dunedin to deliver it.

SIXTH MEETING: *7th September, 1910.*

Present: Mr. A. M. Wright (Vice-President), in the chair, and fifty others.

New Member.—Mr. R. G. Ross.

Letter from Sir Joseph Hooker.—A letter was received from Sir Joseph Hooker acknowledging the receipt of the two volumes of the "Subantarctic Islands of New Zealand." It was resolved that the Council of the Institute be instructed to preserve the letter in a fitting manner, and deposit it among the papers of the Institute as one of the most valued documents in its possession.

Address.—"Modern Views of the Constitution of Matter," by Dr. H. G. Denham.

The lecturer said that two of the most important problems that remain more or less unanswered are the constitution of matter and the nature of electricity. A vast amount of experimental research has, however, led many of the ablest physicists of the world to the view that these two problems are very closely interwoven—in fact, that electricity and matter are really two manifestations of the same phenomenon.

The lecturer then proceeded to describe the experimental evidence that has led physicists to this conclusion, illustrating his remarks by experiments and lantern-slides. After explaining the nature of the cathode rays, he proceeded to the more

recent work of Thomson, Lenard, Lorenz, and others, showing how these scientists have been able to establish the existence of negatively charged electrons in matter. The mass of these electrons has been found to have an exceedingly small value, being in fact only one-thousandth part of the hydrogen atom, which we had hitherto supposed to be the smallest part of matter capable of separate existence. Moreover, research has led to the interesting discovery that this mass is not mechanical, but electric in origin, and is really due to the rapid motion of a charge of electricity. Thomson has thus been led to put forward the tentative view that all matter is electric in origin, the atoms of all elements containing these negatively charged electrons in rapid rotation inside a positively charged sphere. These electrons are differently arranged in the atoms of the different elements, but the arrangement is always the same in the atoms of the same element. On this supposition it is possible to give a real meaning to the periodic table of the chemist; for a periodic arrangement of the electrons would necessarily lead to a periodic recurrence of many chemical and physical properties.

In conclusion, the lecturer quoted from the presidential address of Professor Sir J. J. Thomson to the British Association last year, wherein he expressed the opinion that the experimental work of the last decade had given new life to physics, but that many a difficult peak must yet be scaled before an outlook over the whole constitution of matter and of the universe can be hoped for.

At the conclusion a hearty vote of thanks was accorded to Dr. Denham for his address.

SEVENTH MEETING: *5th October, 1910*

Present: Mr. R. M. Laing (President), in the chair, and fifty-five others.

New Members. Mr. J. A. Pannett and Dr. C. Morton Anderson.

Letter from Dr. W. S. Bruce.—A letter was received from Dr. W. S. Bruce acknowledging the receipt of a copy of the "Subantarctic Islands of New Zealand," and congratulating the Institute on its production.

Hocken Memorial Fund.—The President drew the attention of members of the Institute to the Hocken Memorial Fund.

Papers.—1. "Note on the Flora of Mount Egmont: a Correction," by Dr. L. Cockayne (see p. 19).

2. "Additions to the Fish Fauna of New Zealand: Part II," by Edgar R. Waite (see p. 19).

3. "A Preliminary Phytogeographical Sketch of the Vegetation of the Mount Arrowsmith District," by Dr. L. Cockayne and R. M. Laing.

The paper deals in the first place with the repopulating of the glaciated areas after the retreat of the ice, using as data the present happenings on river-bed at the terminal faces of glaciers, on *débris*, and so on.

The various soils are discussed, especially the wind-blown rock-flour, the "loess" of the authors. The climate of the district is classified as steppe and forest climate, and the limits of these are defined.

Wind is cited as an ecological factor of paramount importance.

The mechanical and physiological effects of snow are briefly discussed, also its relation to the installation of steppe or fellfield psychrophytes. Short periods of drought are considered to strongly favour xeromorphy.

The body of the paper deals with the plant-associations, and the growth-forms of their members. The vegetation is treated of from the dynamical standpoint, and the associations fall into two categories—namely, the steppe series and rock-fellfield series, or, in the forest climate, the rock-forest series. It is further shown how the same climax association may arise from different beginnings.

The paper concludes with a list of species noted in the district, arranged according to the system of Engler, and a short bibliography.

4. "The Post-glacial Climate of Canterbury," by R. Speight.

In this paper the author advances tentatively an hypothesis that during the great extension of the glaciers in Pleistocene times the climate was in all probability steppe-like in character over the eastern slopes of the Southern Alps, and that at a subsequent time it became much moister than at present, this moist climate being succeeded by the present modified steppe conditions. This hypothesis is based partly on geological and partly on biological considerations. The following facts are cited in this connection: Extensive forests once existed over areas which are now treeless and dry; peat bogs appear to be shrinking; the land *Mollusca* are also of a wet-climate type, and not suited to their present surroundings. It is admitted that the evidence put forward is suggestive rather than convincing, but the author hopes that the paper may serve to draw attention to a question which has attracted considerable attention in other parts of the world, and that some work may be done here to correlate distant changes with those that occurred here—if, indeed, these changes took place.

Eighth Meeting: *19th October, 1910.*

Present: Mr. R. M. Laing (President), in the chair, and twenty-five others.

Animals Protection Act.—A letter was received from Colonel R. Heaton Rhodes, M.P., *re* the proposed alterations in the Animals Protection Act, and also a copy of the Act introduced into Parliament by Sir W. J. Steward, M.P.

The following resolution was carried: "That this meeting of the Institute most heartily approves of the Bill introduced into Parliament by Sir W. J. Steward to provide for the protection of birds indigenous to the Dominion, and hopes that it may be accepted by the House during the present session of Parliament."

Dr. Moorhouse expressed, on behalf of the Canterbury Acclimatization Society, its hearty support of the measure.

Papers.—1. "The Geology of the Kermadec Islands" by W. R. B. Oliver.

Abstract.

The physical features and geological structure of the islands comprising the Kermadec Group are described, and an attempt is made to record the order in which the various volcanic materials were laid down.

The islands are built up almost entirely of volcanic matter, but fragments of hornblende granite are included in the pumice tuffs forming the most recent crater in Sunday Island, whilst some of the older tuffs, which are submarine, contain fossil corals and molluscan shells. According to the author's observations, the first eruptions were submarine, but shallow-water conditions obtained. The structure of Sunday Island shows it to be built up in comparatively recent times on a submerged base, and that it never exceeded its present dimensions more than can be accounted for by marine denudation. It is contended that there is no evidence to prove that any land actually existed above sea-level in the vicinity of the Kermadecs when the first volcanic eruptions which resulted in the present islands took place.

The biological evidence which, with apparent exceptions, seems to support the supposition of an oceanic origin for the Kermadecs is briefly reviewed. The presence of the Pacific rat (*Mus exulans*), the candlenut-tree (*Aleurites moluccana*), and the Polynesian ti (*Cordyline terminalis*) is perhaps suggestive of a continental connection; but the author has elsewhere given reasons for supposing these to be introduced by Natives, of whose occupation on Sunday Island there is ample evidence.

2. "On some Further Experiments on the Effect of Artesian Waters on the Hatching of Trout," by C. Coleridge Farr, D.Sc., and D. B. Macleod, M.A.

The experiments and observations recorded in this paper are a continuation this year of those carried out in the winter of 1909 by Farr and Florance. Further evidence is adduced that both the mortality amongst the unhatched eggs and the disease known as "blue swelling" are due to want of aeration, and diminish as the water becomes more normal in its gas-content. An endeavour is made to decide the particular constituent in excess or defect in the water to which the troubles are due. The evidence points to their being either owing to the little oxygenation of the water, or to there being too much radium-emanation in it. Excess of nitrogen exists in the water, as with last year's result, and the possibility of either the mortality of the eggs or "blue swelling" being due to this is discussed and shown to be small. The thanks of the authors are cordially tendered to the Council of the Acclimatization Society, and to Mr. Charles Rides, the director of the fish-hatchery.

3. "On the Physiological Effects of Radium-emanation," by W. H. Symes, M.D.

The author gave a general account of the properties of radium, paying special attention to those relating to its enormous energy. He then summarized the known effects of the emanation on different diseases and pathological conditions, the question of its effect on cases of cancer and goitre receiving the attention that the prevalence of those forms of disease demands. At the conclusion a very hearty vote of thanks was accorded to Dr. Symes for his interesting and informing address.

HAWKE'S BAY PHILOSOPHICAL INSTITUTE.

THIRD MEETING: *5th August, 1910.*

The President, Dr. Henley, in the chair.

New Member.—Mr. Cecil Cornford.

Paper.—"The Philosophy of the Superman," by W. Dinwiddie.

This was an outline of Nietzsche's philosophy, and was illustrated by extracts from several of his works. A short discussion followed.

FOURTH MEETING: *26th August, 1910.*

Mr. W. Kerr in the chair.

Paper.—"Manual Training: its Development in New Zealand, and its Effect on the Child," by W Fossey.

The paper showed the aims and methods of manual training, and dealt at length with woodwork and cookery. Many interesting specimens of pupils' work were shown, particularly in brushwork.

FIFTH MEETING: *7th October, 1910.*

Present: Dr. Henley, President, and fifty-one others.

Paper.—"The Geology of Scinde Island, with special Reference to the Composition and Origin of certain Layers in the Napier Hills," by W. Kerr, M.A.

The various materials entering into the composition of the Napier rocks were described in connection with the succession of strata observed. Special attention was called to the variety of clays found in close apposition with the limestone, both upper and lower.

Elevation and depression of the island as a whole, together with the chief relief features, were discussed, and suggestions made as to the origin of the sands and clays.

The succession of layers forming the highest strata was described at length: it was pointed out that these layers follow the present contours of the surface, and consist largely of materials of volcanic origin. Their composition and probable mode of deposition were described.

The origin of the shingle so abundant on the shores of the island and interbedded in it or its neighbourhood was discussed in connection with the evidences of glaciation; and typical fossils were named as affording a clue to the age of the Napier rocks.

The various features were illustrated by a number of specially prepared slides.

PAPERS AND ABSTRACTS.

1. Note on the Flora of Mount Egmont: a Correction. By L. Cockayne, Ph.D., F.L.S. (Read before the Philosophical Institute of Canterbury, 5th October, 1910.)

In my report on the botany of the Tongariro National Park, page 32, I have inadvertently stated that the flora of Mount Egmont is "richer" than that of Tongariro-Ruapehu, though the statement is discounted by the redundant words "and contains certain species absent on the volcanic mountains of the centre," which, of course, it would of necessity do if "richer."

In point of fact, the flora of Mount Egmont is poorer than that of the central volcanoes, so far as is known, my notes taken in January, 1906, together with the species given in Cheeseman's "Manual" and elsewhere, showing a total of only ninety-seven species of spermophytes and pteridophytes for the subalpine and alpine belts, as against more than 265 for the subalpine and alpine volcanic plateau.

On the other hand, the slopes of Mount Egmont above the forest-line possess a distinctly richer vegetation, and it was evidently vegetation, and not flora, to which the word "richer" was meant to apply. Therefore, to read correctly, the word "vegetation" should be substituted for the word "it" after the word "but" on page 32, line 53.

2. Additions to the Fish Fauna of New Zealand: No. II. By Edgar R. Waite, F.L.S., Curator, Canterbury Museum. (Read before the Philosophical Institute of Canterbury, 5th October, 1910.)

The whole of the fishes collected by me during the cruise of the "Nora Niven," 1907, having now been examined, the following are believed to be new to science or to the known fauna of New Zealand, as indicated.

The first part of the report was published in the "Records of the Canterbury Museum," vol. i, 1909, p. 131 *et seq.*, and a first epitome of subsequent additions appeared on pp. 25 and 26 of the present publication.

Rexea gen. nov.

Family *Trichiuridae.* Body moderately elongate, fusiform. Mouth large, with a single row of dagger-like teeth in each jaw, three enormous fangs towards the front of the upper jaw, and two smaller ones in the lower jaw; teeth on the palatines, none on the tongue. Two contiguous dorsal fins; two finlets above and below; pectorals small and low; ventrals small, each with four spines; caudal forked; peduncle without keel. Scales small and smooth. Lateral line single anteriorly, but divides, and forms an upper and lower branch.

This genus is near to *Promethichthys* Gill, differing principally in the character of the ventral fins and in the configuration of the lateral line. It includes the type below diagnosed, *Thyrsites prometheoides* Bleeker, *T. micropus* McCoy, and possibly *T. (Promethichthys) bengalensis* Alcock.

Rexea furcifera sp. nov.

B., vii; D., xviii, ii, 15, ii; A., ii, 14, ii; V., iv; P., 14; C., 18 + 8.

Length of head, 3·2; height of body, 1·1; and length of caudal, 6·9 in the length. Diameter of eye 1·8, interorbital space 4·6; and length of snout, 2·4 in the head.

The length of the maxillary is half that of the head, and it extends to the anterior of the orbit; it bears twenty acute, flattened, distantly set teeth; the vomer has three large dagger-like teeth; the palatine teeth are similar to the maxillary ones, but smaller. The lower jaw markedly projects, and its extremity completes the anterior contour of the head; two large teeth at the symphysis remain without the upper jaw when the mouth is closed.

The first dorsal fin arises within the vertical of the opercular margin, and the middle spines are longest; the fins are subcontinuous.

Scales: Cheeks, opercles, and body sealy, the scales small; the lateral line passes almost straight from above the opercle, near to the dorsal edge, to beneath the middle of the soft dorsal. Beneath the base of the v vi dorsal spines it sends off a downward branch which descends suddenly to the mid-line of the body, thence straight to beneath the origin of the soft dorsal, and terminates in advance of the middle caudal rays.

Colours: Iridescent blue above, silvery beneath; a deep black blotch on the dorsal between the i iii spines, the fin narrowly edged with black; soft dorsal, anal, and caudal orange.

Length, to 711 mm.

This species has been entered in the New Zealand lists as *Promethichthys prometheus*.

Ammotretis nudipinnis sp. nov.

B., vii; D., 85; A., 60; V., dex. 7, sin. 4; P., dex. 11, sin. 12; C., 11 | 4; scales, 82.

Rostral flap very long, extending downwards below the level of the maxilla, mouth large, a broad band of teeth in each jaw on the blind or left side only. Eyes on the same level; interorbital space equal to the longitudinal diameter of the eye.

The dorsal rays commence at the tip of the rostral flap, the first five or six are free; the dorsal and anal are coterminal, close to the outer caudal rays; the right ventral is very long and connected with the anal, last ray of left ventral opposite to the vent.

Scales: Strongly ctenoid on the right, smooth on the left side. No scales on the fin rays, the caudal excepted.

Colours: Warm brown above, reddish towards the margins, irregularly blotched with dark brown; under-side colourless or more or less blotched.

Length, 482 mm.

This species differs from *A. rostratus*, with which it appears to have been confounded, by the scaleless dorsal and anal fins, the smooth character of the scales on the left side, and the wider interorbital space.

Pelotretis gen. nov.

Family *Pleuronectidae*. Eyes on the right side, the lower advanced. Mouth small, subsymmetrical; teeth on the blind side only, no vomerine or palatine teeth. The dorsal commences behind the snout, and is not connected with the caudal. Two ventrals, the right one in the same line and continuous with the anal. Scales moderate, ctenoid on the right side; lateral line nearly straight. Gill-openings narrow, the membranes broadly united beneath the throat; gill-rakers short and conical.

This genus differs from *Ammotretis* by the small subsymmetrical mouth, the large eyes, the upper of which is close to the profile, the backward origin of the dorsal fin, and the absence of any rostral prolongation.

Pelotretis flavilatus sp. nov.

B., vii; D., 89; A., 71; V., dex. 7, sin. 5; P., dex. 12, sin. 11; C., 13 | 4; scales, 78.

Length of head, 4·8; height of body, 1·8; length of caudal, 5·0 in the length; diameter of eye, 3·9 in the the head.

The eyes are large, crowded to the front of the head, and the upper one is close to the dorsal edge, which is incised so that the eye can be seen from the under-side; lower eye slightly advanced, separated from the maxilla by a narrow ridge only.

The dorsal fin begins above the front edge of the eye, and none of the rays is entirely free; the longest are 2·2 in the head.

Scales: Imbricate, ctenoid on the right side, smooth but striated on the left. Head, body, and fin-rays (ventrals and anterior rays of the dorsal and anal excepted) covered with scales.

Colours: Grey or brown above; both body and fins with irregular though well-defined markings, sometimes absent; under-side yellow.

Length, 311 mm.

This is the common "lemon sole" of the colonists, and does not appear to have been previously diagnosed, the name having been erroneously associated with *Ammotretis rostratus*.

Gnathagnus innotabilis Waite.

Three specimens were originally taken off the coast of New South Wales, and those now recorded constitute a record for New Zealand, the genus not being previously known from our waters.

Several examples were obtained in the Bay of Plenty, at depths from 25 to 91 fathoms. The largest specimen previously known was 152 mm. in length, but specimens trawled in New Zealand show that it attains much greater dimensions, up to at least 560 mm

Kathetostoma giganteum Haast

The species of *Kathetostoma* hitherto regarded as *K. laeve* is distinct from the Australian species, differing in relative proportions and in colour-markings. The name *K. giganteum* is to be used for the New Zealand form.

3. **The Alkaloids of the Pukatea.** By B. C. Aston. (Journ. Chem. Soc., xcvii, pp. 1381–87. July, 1910.)

In addition to the author's previously published work (see Proc. N.Z. Inst., 1909, pt. ii, p. 56), the methods of preparation, description, and analyses of the salts of the alkaloid Laureline $C_{19}H_{21}O_3N$, the sulphate $(C_{19}H_{21}O_3N)_2H_2SO_4 7H_2O$, the hydrochloride $C_{19}H_{21}O_3N\ HCl$, and the nitrate $C_{19}H_{21}O_3N\ HNO_3$, are given. The provisional formula $C_{18}H_{19}O_3N$ is suggested for a third alkaloid, neither the base nor the salts of which could be obtained in a crystalline state. Pukateine, $C_{17}H_{17}O_3N$, is shown to possess feebly acid properties in the presence of a strong base, forming salts with the alkali metals of the formula $C_{17}H_{16}MO_3N$ (M — K or Ne) and to have an optical activity of α^{15}_{D} 220°.

B. C. A.

4. **Pflanzengeographie.** By L. Diels. Pp. 163, with 1 map. Leipzig: G. J. Götschen'sche Verlagshandlung, 1908.

This book is of interest to New Zealand botanists not only because it states clearly and briefly the fundamental principles of phytogeography, but because there are some important remarks regarding the New Zealand flora.

The subject-matter is treated under four heads—namely, floristic plant-geography, ecological plant-geography, genetic plant-geography, a synopsis of the floral regions of the earth.

The term "plant formation" is used in its broadest sense, and the following are given as types of vegetation applicable to the whole earth: (*a*) Sea vegetation (thallassium); (*b*) fresh-water vegetation (limnium); (*c*) mangrove (halodrymium); (*d*) rain-forest (hygrodrymium); (*e*) monsoon-forest (tropodrymium); (*f*) summer forest (therodrymium); (*g*) coniferous forest (conodrymium); (*h*) dry forest (xerodrymium); (*i*) heath (mesothamnium); (*k*) savannah (mesopoium); (*l*) steppe (xeropoium); (*m*) meadow (hygropoium); (*n*) meadow-moor (low-moor, hygrophorbium); (*o*) moss-moor (high-moor, hygrosphagnium); (*p*) mat-vegetation—"matte" (mesophorbium) [This is the "mat-grassland" and "mat-herbage" of Warming, and is represented in New Zealand by the closed association of herbaceous and suffruticose plants on the wetter mountains]; (*q*) dry pasture, "trift" (xerophorbium), defined by the author as a formation of perennial herbs occurring in a climate with a low rainfall, or on dry ground, the eastern slopes of the Southern Alps of New Zealand being cited as a noteworthy example, where on the stony ground of the east an open xeromorphic pasture ("trift") offers a great contrast to the closed mat-herbage ("matte") of the western slopes.

Part iv, dealing with the divisions of the plant world, is based on the opinion that in estimating phytogeographical areas the facts of floristic, genetic, and ecological plant-geography must all be considered, though the two first-named branches must supply the details first to be considered.

The following is the classification proposed: (1.) The Palaeotropic Floral Kingdom (Palaeotropis). This comprises the tropical lands of the Old World and their descendants in the plant-geographical sense. It is subdivided into

(*a*) the Malesian Province (Malesicum), (*b*) the Indo-African Province (Indo-Africanum). (2.) The Cape of Good Hope Province (Capensis). (3.) The Holoarctic Province (Holarctis). This comprises the frigid and temperate zones of the Northern Hemisphere. It is subdivided into (*a*) the East-Asian Province (Oriasiaticum); (*b*) the Central Asian Province (Centralasiaticum); (*c*) the Mediterranean Province (Mediterraneum); (*d*) the Eurasian Province (Eurasiaticum), which extends from Iceland to Kamtchatka; (*e*) the North American Province (Septamericanum). (4.) The Neotropical Floral Kingdom (Neotropis). This includes Central and South America, excepting that portion of the latter belonging to the next floral kingdom. (5.) The Antarctic Floral Kingdom (Antarctis). This comprises Fuegia, southern Patagonia, south-west Chile, the Subantarctic Islands, including those of New Zealand and Antarctica. (6.) The Australian Floral Kingdom.

The Malesian Province and the Antarctic Kingdom specially concern New Zealand. The former extends from Ceylon on the west through the Malay Archipelago, and puts out three arms eastwards and southwards. The middle arm is the richest. It includes Melanesia from the Solomon Islands by way of the New Hebrides and New Caledonia to New Zealand. The eastern arm includes Micronesia and Polynesia. The western arm crosses to Australia, and extends along the east coast in a narrow band southwards, so that a trace reaches Tasmania.

New Zealand appears both geographically and biologically to be the remains of an area almost continental in extent, which may have extended to Norfolk and Lord Howe Islands. But the groundwork of the flora may be considered Malesian, though the formations, through the great variation of surface, &c., of the islands, are of many kinds, and bear a distinct stamp owing to the extreme abundance of *Coniferae*, ferns, and certain other groups which do not require a hot climate. The north and the very moist south-west coast are occupied by rain-forest, but the east by heath, grassland, and dry open pasture ("trift land"). The high mountains of the south offer a sharp distinction between the vegetation of their windward and lee slopes.

Besides the Malesian floral element, one altogether different appears the further south one goes, or the higher one ascends. It occurs also in Tasmania and on the higher land of east Australia, shows a strong affinity to the extreme south of South America, and for a long time has been known as Antarctic. This element dominates the alpine floras of New Zealand and Tasmania, but in the lowlands the part it plays is too trifling to make desirable the separation of New Zealand from Palaeotropis.

The author regards the Auckland and Campbell Islands as the last remnant of a mountain-axis which extended to New Zealand proper. As for the Antarctic flora in general, it is considered a remnant of one much more extensive which formerly occupied the Antarctic lands, and whose traces still remain in the fossils of Seymour Island and the remains of trees on Kerguelenland. L.C.

5. On the Fossil Osmundaceae. By R. Kidston and D. T. Gwynne Vaughan. (Trans. Roy. Soc. Edinb., vol. 45, pp. 759–79; Vol. 46, pp. 213–32 and 651–67; vol. 47, pp. 455–76, pl. 22. 1907–10.)

This most important memoir gives detailed descriptions, illustrated by admirable microphotographs, of a number of stems of fossil ferns referred by the authors to the *Osmundaceae*.

Two of the specimens described were discovered in certain Jurassic rocks near Gore, Southland, the one by Mr. R. Dunlop, formerly of Orepuki, and the other by Mr. R. Gibb. Both plants are described as new species, under the names of *Osmundites Dunlopi* and *O. Gibbiana* respectively.

The two specimens agree in all essential characters with the stems of the modern *Osmundaceae*.

An examination of the distribution of the various sclerotic strands that occur at the base of the fully developed petiole of a number of living species of *Osmundaceae* showed that it was characteristic of, and practically constant in, each species examined, but it varies sufficiently to be suitable for a mark of comparison. Judged from this standpoint, the leaf-base of *Osmundites Dunlopi* comes very near that of *Todea barbara* of the present New Zealand flora; while that of *O. Gibbiana*, although in some respects unique, approaches nearest to *O. regalis* and *O. javanica*,

The most important character that shows any considerable variation in the living species (apart from *Osmunda cinnamomea*) is the extent of the interruption in the continuity of the xylem ring caused by the departure of the leaf-traces. *Osmunda regalis* represents one extreme, where the xylem ring is broken up into many distinct strands free from one another, while the other extreme is shown by *Todea barbara* and *T. superba*, in which the strands are fused with each other and with the xylem of the leaf-trace, so forming continuous bands. As regards the two fossil species, *Osmundites Dunlopi*, with its continuous xylem ring, points in the direction of *Todea barbara*, while *O. Gibbiana* points in the direction of *O. regalis*, and the authors consider that amongst the living *Osmundaceae*, "so far as our data permit us to judge," *T. barbara* shows most resemblance to *O. Dunlopi*, and *O. regalis* to *O. Gibbiana*. But until the sporophylls are known the species are to be kept in the fossil genus *Osmundites*.

An unnamed *Osmundites* in the British Museum collection, said to have come from New Zealand, was examined, and was found identical with *O. Dunlopi*.

Besides the two species mentioned above, all the recorded fossils of an osmundaceous character are dealt with excepting one. A table is given showing the chronological order of the species, and a synopsis of their more important anatomical features. This latter shows that the medullation of the stele and the subsequent breaking up of the xylem ring takes place *pari passu* with the advance from the older to the younger strata. The age of the fossils is as follows: Upper Permian, 5; Jurassic, 2; Upper Jurassic, 1; Lower Cretaceous, 1; Lower Eocene, 1; Lower Pliocene or Upper Miocene, 1.

Dealing with the ancestry of the *Osmundaceae*, the authors consider them, as a whole, as "an ascending series of forms whose vascular system is to be derived from a primitive protostele with a solid homogeneous xylem," by the medullation of which and the subsequent breaking-up of the peripheral xylem ring thus formed into separate strands the typical osmundaceous stele has been derived.

By a consideration of the methods through which the medullation of the stele has come about, the authors find the existence of an intermediate stage in which the pith consists of tracheae mixed with parenchyma, and it becomes inevitable that the mixed pith of the *Zygopterideae* is of the same nature and origin as that of the *Osmundaceae*, especially as the authors believe the two families have descended from a common ancestor. Further, the authors postulate the discovery of a primitive zygopterid stele with a solid xylem mass, the central tracheae of which are short, and transitional toward a pith, as in two of the osmundaceous genera dealt with.

This prophecy was confirmed by the discovery of a stele exactly as anticipated by W. T. Gordon, a figure of which is given.

The monograph concludes with an attempt to explain the derivation of the specialized leaf-trace of the *Zygopterideae* from the simple primitive form of the *Osmundaceae*. L. C.

6. The Morphology of the Podocarpineae. By Mary S. Young. (*Botanical Gazette*, vol. 50, pp. 81–100, pls. 4–6. August, 1910.)

Before the year 1902 very little was known regarding the morphology of the *Podocarpinaceae*, but since that date a number of investigators, using in large part material from New Zealand, have found out a good deal about the group, the only genus yet untouched being *Pherosphaera*, with its two species. Of special interest is the question of relationships of the *Podocarpineae*, particularly with regard to the *Araucarineae*.

The paper deals first with the gametophytes of *Phyllocladus*, the authoress having examined a considerable amount of material of *Phyllocladus alpinus*, which had been collected by the reviewer at fairly regular intervals from the 16th October to the 28th January. A full account is given of the male and female gametophytes, and of the process of fertilization, and there is something as to the development of the embryo. The conclusion come to by the authoress regarding the affinities of *Phyllocladus* is that it is a relatively primitive member of the *Podocarpineae*, which branched off from them a comparatively short time after their separation from the *Taxineae*. This conclusion is based on the following: (1) *Phyllocladus* has primitive characters of the *Taxineae* which are being eliminated in the *Podocarpineae*; (2) it has primitive characters of the *Podocarpineae* which have been entirely eliminated in the *Taxineae*; (3) it has some advanced characters of *Podocarpineae*; (4) the taxad resemblances are more superficial and variable, and the podocarp features more fundamental.

The remainder of the paper deals with the relationship between the *Podocarpineae* and the *Araucarineae*. The authoress brings together the available facts from the different publications bearing on the subject. She comes to the conclusion that the *Podocarpineae* and *Araucarineae* are very primitive, and that they are probably related; but the question is by no means settled. There are various gaps in our knowledge, especially regarding the *Araucarineae*, the female gametophyte of which is little known, while of the embryo we know virtually nothing. In the *Podocarpineae*, too, adequate knowledge is wanted of the female gametophyte, embryo, and the development of ovulate structures. Wanting the above knowledge, "we should be hardly justified in coming to a definite decision in regard to relationships, and at present it seems best to hold *Taxineae*, *Podocarpineae*, and *Araucarineae* apart as separate tribes, leaving open the question of larger grouping amongst conifers." L. C.

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7. **Trees and Shrubs of New Zealand.** By L. S. Gibbs. (The *Gardener's Chronicle*, vol. 47, pp. 97, 98, 118, 131. February, 1910.)

An account of New Zealand trees and shrubs with regard to their value as plants for cultivation in English gardens, for which purpose the authoress recommends a number highly. The statement is made, "that beyond *Cordyline australis* and tree-ferns it is rare to see a native shrub or tree in a New Zealand garden." With the exception of *Pittosporum Kirkii*, the other species of the genus are described as "uninteresting." L. C.

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8. **Pratia angulata Hook. f., and Lobelia linnaeoides Petrie.** By J. B[ayley] B[alfour]. (The *Gardener's Chronicle*, vol. 47, p. 98. February, 1910.)

Both the above plants are hardy in the Edinburgh Botanic Garden. *Pratia angulata*, although growing in damp situations in New Zealand, and noted by Cockayne as a bog-plant in Stewart Island, when grown in dry sandy soil in the full sun in Edinburgh forms a close carpet on the soil, and every leaf-axil sends up a short-stemmed flower, making during the summer a perfect sheet of white blossom. If the plant be grown in the shade, or where the soil is heavier and moister, the stems arch from the soil, forming more or less of a cushion, grow freely, and the flowers, which are produced in fair abundance, are concealed amongst the greenery and make little show. L. C.

9. **Deforestation in New Zealand.** By L. S. Gibbs. (The *Gardener's Chronicle*, vol. 44, pp. 355–56; November, 1908: and vol. 45, pp. 225–26 and 243–44; April, 1909.)

The authoress, who spent six months in New Zealand, gives, in three articles, her views regarding the wholesale destruction of forest in the Dominion, and the methods pursued. The observations were made chiefly from the most frequented tourist routes. The following extracts show the scope of the articles:

"The results of deforestation everywhere to be witnessed in the country between Auckland and the Bluff were such as to create an impression as painful as it was indelible. Past and present evidences of the effect of the destruction haunt me everywhere, from the barren plains and barren hills of the older 'settled' districts in the one case, to the miles of blackened tree-stumps, even on much-advertised tourist routes, in the other." "These results are caused by the requirements of the settlers; for, unfortunately, they and devastating bush-fires always go hand-in-hand. Once the fire has done its worst, English grass-seed is immediately sown, and cattle and horses are turned loose amongst the standing and prostrate logs, which are left to rot on the ground. A little homestead will be run up amidst the *débris*, a couple of rectangular paddocks will be, perhaps, cleared of the roots of the trees and enclosed by a hedge of *Pinus pinaster* (erroneously called *P. insignis*) and *Cupressus macrocarpus* respectively as wind-screens, and the result is a typical New Zealand landscape. To have the pine without the cupressus would be wanting in imagination and taste." "The remaining forest land is generally Government property, and is leased in 'sections,' which, when large areas are opened up, are put up to auction. This land may be covered with the most splendid forest-growth, such as the Waimarina Bush, now being cut up by the Main Trunk Railway from Wellington to Auckland,

which has been purposely run through it." "The region in question, like the greater portion of the North Island, is of a soapstone or 'pappa' formation, which weathers into a clammy clay." "Cleared in the usual wasteful fashion, ... not only are the uninteresting contours of the country exposed to view, but the forest is replaced by a weedy upgrowth of *Fuchsia excorticata* and *Aristotelia racemosa*, mixed with any and every species of the heterogeneous mass of herbaceous and shrubby aliens, which are ever ready to invade fresh areas, turning a natural garden into a vegetative slum." "The disreputable Maori who idled our canoe up-stream voiced, parrot-like, the cry of the country, 'Too much bush; too few children.' 'Bush is there to be burnt, and the sooner the better. It is a most contemptuous and unfortunate term."

Speaking of the South Island, after explaining the effect of the Dividing Range on the rainfall and distribution of forest, the authoress writes, "The mixed forest of the West Coast is too soaked with moisture to burn easily . . . . but all the best trees are being rapidly cut out by sawmills.' "The natural forest-growth, if worked on scientific principles, would form a magnificent asset to the resources of any country. As it is, in such mixed forest, each kind of tree is limited in numbers, and, when cut without regard to age, only the old and aborted specimens are left standing, and the forest is, in consequence, unable to regenerate itself. The resulting thinning alters the prevailing conditions as to light, moisture, and wind, and allows the ingress of rabbits, which devour all young vegetation, and so prepare the way for an army of alien herbaceous plants and shrubs, including blackberries, sweetbriar, gorse, and broom, which luxuriate in the virgin soil. Fungal diseases attack the weakened indigenous trees, which will have no further chance to re-establish themselves; so that all commercial value in wood, which forms one of New Zealand's exports and its chief scenic charm, goes into the pocket of the first man who comes to enjoy the unrestricted exploitation of the virgin forest." "Once through the [Otira] Gorge, we enter the country of dry rainless winds and tussock plains beyond, between bare tussock hills, yellow even in the beginning of December; all sheep-runs, the grass burnt off every year, and rabbits ubiquitous. Here one shrub, *Discaria toumatou*, or 'wild Irishman,' holds its own. It is a veritable mass of thorns (arrested branches), with inconspicuous green leaves and white flowers. It grows singly in the wide river-beds, on sheltered mountain-slopes, and in the plains. Otherwise not a tree is visible—that would mean fewer sheep to the acre; and the unfortunate animals in the blaze of the sun find such shelter as they may under the *Discaria*. It is a familiar sight to see them crowding under what can be only shade in their imagination, and it makes one question whether it is really advantageous, or is merely an atavistic idea inherited from ancestors accustomed to more luxuriant conditions. These places must all have been wooded at some time not far distant. Nothing else could account for the extraordinary paucity of herbaceous plants, of which *Craspedia uniflora* is one of the few which occurs in any quantity on the plains."

Speaking of the Mackenzie country, it is stated, "These plains, thanks to the agency of man, run up to the foot of Mount Cook, and, as far as I could make out, they constitute the subalpine meadows of New Zealand ecologists." "It is a three-days drive from Mount Cook to Lake Wanaka, and for the whole way there is no native tree to be seen. I was told there was 'bush' in the back country, so that it must once have existed in the front; but this country of huge sheep-runs, where every station has to keep a gang of rabbiters, tells its own tale. Deer have been also introduced, and are increasing to a large extent, much to the disgust of the runholders." "At Lake Wanaka . . . . there was the same baneful deforestation, sheep-run bareness, and poverty of soil. The mountains in the background show up green, for the runs have not got so far back yet."

A brief description is given of the Clinton and Arthur Valleys, and of their suitability as a sanctuary for the indigenous flora and fauna. The articles conclude as follows:—

"Isolated reserves here and there are of no value from a physiographical, economic, or rainfall point of view. In a naturally wooded country like New Zealand the question should be treated as a whole on some recognized plan drawn up by competent forest officials who have been trained not only in the great schools of Nancy, Munich, and the magnificent economic forests of France and Germany, but also in the management of virgin forest, which under scientific guidance has achieved such a success in India." "India is in the happy position of being able to treat questions from a scientific rather than a party standpoint. In New Zealand the Government alone can act in the matter, as for economic reasons the private owner is helpless and the mere occupier indifferent. Labour costs 10s. a day, and is difficult to obtain at that: therefore private enterprise is discouraged."

L. C.

10. Ourisia modesta Diels, eine neue Art Neuseelands. By L. Diels. (Fedde, Repertorium, Vol. 7, p. 114. 1909.)

The following is the original description of *Ourisia modesta* Diels, an incomplete account of which was given by Cockayne in his "Report on a Botanical Survey of Stewart Island," p. 44 :--

"Herba minuta. Caulis procumbus repens radicans. Foliorum petiolus hinc inde villosulus vel ciliatus, 2-4 mm. longus; lamina crassiuscula glabra, e basi leviter cordata reniformis vel rotundato-elliptica, 3-5 mm. longa, 2·5-4·5 mm. lata; flores solitarii; pedunculus 5 mm. longus; calyx 4- (rarius 5-) lobus, tubus circ. 5 mm. longus, lobi 1·5 mm. longi, lati, obtusi; corolla 5-fida, tubus 4 mm. longus 2·5 mm. latus, lobi anguste elliptici apice truncati vel levissime emarginati 3·5 mm. longi, 1·5 mm. lati; staminum antherae reniformes, loculi demum confluentes; ovarium glabrum ovoideum 1·5 mm. longum, sylus 2·5 mm. longus; stigma capitato-discoideum.

"Neu-Seeland: Stewart Island, Rakiahua Valley, auf nassem Boden (Dr. L. Cockayne!).

"Species minuta *Ourisiae caespitosae* Hook. f. atque eius varietati *gracilis* Hook. f. proxima videtur, sed petiolis longioribus et floribus multo minoribus facile distinguitur." L. C.

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11. Pecten multisquamatus Dunker, and Pecten radiatus Hutton. By M. Bavay. (Bulletin du Muséum National d'Histoire Naturelle, Paris, 1909, No. 5, pp. 277–80, pl. iv, fig. A.)

Diagnosis of *Pecten (Chlamys) radiatus* Hutton: Shell rather thin, orbicular, very little convex, nearly equilateral, inequivalve, the right valve a little more convex than the left, finely ribbed, the riblets spreading radially from the beak, dividing into two or three, this process being repeated once or several times, and thus the number of riblets is increasing with the distance from the beak. There are 100 to 150 riblets, according to the size of the valves, and amongst them about 20 are stronger than the others. The riblets are, except at the beak, ornamented with small, transverse, erect, and close scales. The ears are unequal, the anterior ears larger, the posterior ears with an oblique margin, all with riblets similar to those of the valves, but they are stronger on the anterior ears. Sinus denticulate, irregularly quadrangular. Colour, purple or orchraceous, paler on the right valve; the umbonal region is either paler or of a deeper tint, sometimes spotted with white.

Hab. The specimens in the Muséum de Paris are from Stewart Island, and also from the Tonga Islands.

Bavay says that the sculpture resembles that of *Pecten Dieffenbachi* Gray (the author of this species is Reeve, and it is a synonym of *P. zelandiae* Gray), and is of the same type as that of *Chlamys islandicus* Müller and *C. rubidus* Hinds--viz., that characteristic of the section *Chlamys*.

The author states that he formerly considered our *Pecten radiatus* to be identical with *P. multisquamatus* Dunker, from the Antilles, and he expressed his astonishment at the wide distribution of the species (Journ. de Conch, vol. liii, 1905, p. 26).

A note and figure published by Mr. C. Hedley, of Sydney (*Chlamys radiatus* Hutton, P.L.S. N.S.W., vol. xxxiii, 1908, p. 472, pl. 10, fig. 28), has, however, convinced Mr. Bavay that he was mistaken in his identification, and he now states that the two species, though nearly allied, are distinct. H. S.

12. Bird-life on the Kermadec Islands. By Tom Iredale. (The *Emu*, vol. x, pt. i, p. 2; July, 1910.)

This paper deals principally with the habits of the birds of the Kermadec Islands, as observed by Mr. Iredale during the year 1908.

The following is the list of the species of birds enumerated :—

I. Resident Land-birds breeding in the Group.

Prosthemadera novae-zealandiae (Tui).

Halcyon vagans (New Zealand Kingfisher).

Cyanorhamphus cyanurus (Parrakeet). A doubtful species, specimens from Macauley Island having been referred by Sir Walter Buller to *C. novae-zealandiae*.

Porzana plumbea (Spotless Crake).

II. Sea birds visiting the Group during the Summer Months to breed.

Sterna fuliginosa (Sooty Tern, Wideawake).
Gygis alba (White Tern).
Micranous leucocapillus (White capped Noddy).
Procelsterna cinerea (Grey Noddy).
Phaethon erubescens (Red tailed Tropic Bird). The Kermadec Island bird has hitherto been referred to *P. rubricauda*.
Sula cyanops (Masked Gannet).
Puffinus chlororhynchus (Wedge-tailed Shearwater).
Puffinus assimilis (Allied Shearwater). Breeds during winter months; arrives in May; eggs plentiful on 3rd August.
Oestrelata cervicalis (Sunday Island Petrel).
Oestrelata nigripennis (Black-winged Petrel).
Oestrelata neglecta (Kermadec Island Mutton-bird). Begins to arrive at Sunday Island in August, leaves in April and May; lays from October to February. On Meyer Islet lays from February to May, the young leaving in August. Mr. Iredale points out that this species, which is very variable in coloration, must include all the petrels breeding on the surface in the Kermadec Islands, and previously known under various names (*mollis*, *philippi*, *leucophrys*, *neglecta*).

III. Visitors: not known to breed in the Group.

Urodynamis taitensis (Long-tailed Cuckoo). Met with in every month of the year on Sunday Island.
Circus Gouldi (?) (Harrier). Noticed on Sunday Island and Meyer Islet from March to October.
Anas superciliosa (Grey Duck). Noted all the year on Sunday Island.
Charadrius dominicus (Lesser Golden Plover). A few birds noticed during September and October on Sunday Island, and in November on Macauley Island.
Ochthodromus veredus (Oriental Dottrel). One bird obtained on Sunday Island in April. This is the first record of this species from the Kermadec Islands.
Numenius variegatus (Whimbrel). One specimen obtained on Sunday Island in September. The first record from the Kermadecs.
Heteropygia acuminata (Stint). One bird shot on Sunday Island in October. The first record from the Kermadecs.
Diomedia exulans (Wandering Albatros). One specimen washed up on the beach, Sunday Island.
Pelagodroma marina (White-faced Storm Petrel). Two specimens washed up on beaches in October.

IV. Species previously recorded from the Group, but not noticed during 1908.

Rallus philippinensis (Pectoral Rail).
Zosterops coerulescens (White-eye).
Anthus novae zealandiae (Ground lark).
Limosa novae zealandiae (Godwit).
Anous stolidus (Noddy Tern).
Daption capensis (Cape Pigeon).
Puffinus tenuirostris (Tasmanian Mutton-bird).

V. Three Birds acclimatized in New Zealand have reached the Group, and have firmly established themselves.

European Song-thrush, Blackbird, and Starling.

R. B. O.

13. On Marine Mollusca from the Kermadec Islands, and on the "Sinusigera apex." By Tom Iredale. (Proc. Mal. Soc. vol. ix, pt. 1, p. 68; March, 1910.)

Notes on certain species of *Mollusca* collected in the Kermadec Islands in 1908 are given, together with the following list, which includes only those that have been identified with already described species:—

1. *Helcioniscus craticulatus* Suter.
2. *H. dirus* Rve.
3. *Ancistromesus kermadecensis* Pils.
4. *Angaria tyria* Rve.
5. *A. distorta* Linné.
6. *Leptothyra picta* Pease.

7. *Nerita melanotragus* Smith.
8. *N. plicata* Linné (= *N. undata* (Linné) Suter, Index Faunae N.Z., p. 81).
9. *Littorina mauritiana* Q. & G.
10. *Tectarius feejeensis* Rve.
11. *Planaxis brasilianus* Lam.
12. *Rissoa carnosa* Webster.
13. *R. candidissima* Webster.
14. *Rissoina polytropa* Hedley.
15. *R. plicata* A. Adams.
16. *Cerithiopsis sinon* Bayle.
17. *Strombus aratus* Mart.
18. *S. urceus* Linn.
19. *S. elegans* Sowb.
20. *Xenophora corrugata* Rve.
21. *Hipponix foliacea* Q. & G.
22. *Natica sagittata* Menke.
23. *N. orientalis* Gmel.
24. *Polinices simiae* Desh.
25. *Ianthina ianthina* Linné.
26. *I. umbilicata* d'Orb.
27. *I. exigua* Lam.
28. *I. globosa* Swain.
29. *Recluzia Hargravesi* Cox.
30. *Cypraea erosa* Linné.
31. *C. caputserpentis* Linné.
32. *Erato lachryma* Gray.
33. *E. corrugata* Hinds.
34. *Trivia napolina* Kiener.
35. *Septa rubicunda* Perry.
36. *Argobuccinum australasia* Perry.
37. *A. siphonatum* Rve. (= *Tutufa* (*Crossata*) *californica* (Hinds) Suter, Trans. N.Z. Inst., xxxviii, p. 328).
38. *A. papilla* Wood (= *Ranella verrucosa*, Sowb.).
39. *Cymatium Spengleri* Gmel.
40. *C. Dunkeri* Lischke.
41. *C. caudatum* Gmel.
42. *C. exaratum* Rve.
43. *C. costatum* Born.
44. *C. labiosum* Wood (= *Triton strangei*, Ad. & Ang.).
45. *C. vespaceum* Lam.
46. *C. Parkinsonia* Perry.
47. *Cassidea pyrum sophiae* Braz.
48. *C. cernica* Sowb.
49. *Dolium pomum* Linné.
50. *D. perdix* Linné.
51. *Architectonica cingula* Kien.
52. *Heliacus variegatus* Gmel.
53. *H. stramineus* Gmel.
54. *Epitonium perplexum* Pease (= *Scalaria australis* (Lam.) Suter, Journ. Malac., vii, p. 54).
55. *Atlanta fusca* Eydoux and Souleyet.
56. *Colus toreuma* Mart.
57. *Mitra mitra* Linné.
58. *M. carbonaria* Swainson.
59. *M. lanceolata* Hervier.
60. *Alectrion spiratus* A. Ad.
61. *A. gaudiosus* Hinds (= *Nassa zonalis* (A. Ad.) Suter, Trans. N.Z. Inst., xxxviii, p. 331).
62. *A. scalaris* A. Ad.
63. *Thais chaidea* Duclos.
64. *T. succincta* Lam.
65. *T. Smithi* Braz. (= *Purpura striata* var. *bollonsi* Suter, Trans. N.Z. Inst., xxxviii, p. 331; *Drupa bollonsi* Suter, Proc. Mal. Soc., viii, p. 254).
66. *Columbella versicolor* Sowb.
67. *Lyria nucleus* Lam.
68. *Coralliophila neritoidea* Lam.
69. *C. nivea* A. Ad.
70. *C. Lischkeana* Dunk.
71. *C. monodonta* Q. & G.
72. *Magilus antiquus* Montf.
73. *Marginella mustelina* Angas.
74. *Turris cingulifera* Lam.
75. *Terebra venosa* Hinds.
76. *Conus vermiculatus* Lam.
77. *C. minimus* Linné.
78. *Pugnus parvus* Hedley.
79. *Bullaria ampulla* Linné.
80. *Bullina scabra* Gmel.
81. *Limacina bulimoides* d'Orb.
82. *Styliola subula* Q. & G.
83. *Clio pyramidata* Br.
84. *C. acicula* Rang.
85. *C. virgula* Rang.
86. *Cuvierina columnella* Rang.
87. *Cavolinia tridentata* Gmel.
88. *C. trispinosa* Lesueur.
89. *C. longirostris* Lesueur.
90. *C. inflexa* Lesueur.
91. *Umbraculum umbella* Mart.
92. *Siphonaria diemenensis* Q. & G. (?).
93. *S. atra* Q. & G.
94. *Gadinia conica* Angas (= *G. nivea* Hutton).
95. *Placunanomia ione* Gray.
96. *Arca foliata* Forsk.
97. *A. domingensis* Lam.
98. *Lima bullata* Born.
99. *Philobrya costata* Bern. (incl. *P. filholi* Bern.).
100. *Modiolus auriculatus* Krauss.
101. *Lithophaga straminea* Dunk.
102. *Septifer bilocularis* Linné.
103. *Modiolaria impacta* Herrm.
104. *Meleagrina vulgaris* Schum.
105. *Melina nucleus* Linné.
106. *Julia exquisita* Gld.
107. *Spondylus ostreoides* Smith.
108. *Codakia bella* Conrad.
109. *Diplodonta zelandica* Gray.
110. *Lasaea miliaris* Phil.
111. *Ervilia bisculpta* Gld.
112. *Chione toreuma* Gld.
113. *Lutraria oblonga* Gmel.
114. *Saxicava arctica* Linné.
115. *Gastrochaena Retzii* Desh.
116. *Chama foliacea* Q. & G.
117. *Nautilus pompilius* L.
118. *N. macromphalus* Sowb.
119. *Spirula spirula* L.
120. *Argonauta argo* L.
121. *A. nodosa* Sol.

PROCEEDINGS

OF THE

NEW ZEALAND INSTITUTE

1910

PART III

EDITED AND PUBLISHED UNDER THE AUTHORITY OF THE BOARD OF GOVERNORS OF THE INSTITUTE

ISSUED 12TH MAY, 1911

Wellington, N.Z.

JOHN MACKAY, GOVERNMENT PRINTING OFFICE

WILLIAM WESLEY AND SON, 28 ESSEX STREET, STRAND, LONDON W.C.

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PROCEEDINGS

OF THE

NEW ZEALAND INSTITUTE.

1910.

PART III.

EIGHTH ANNUAL MEETING.

The annual general meeting of the Board of Governors of the New Zealand Institute was held in the Auckland Museum Library, Auckland, on Thursday, 26th January, 1911.

Present: Mr. A. Hamilton, President (in the chair), Professor W. B. Benham, F.R.S., Dr. L. Cockayne, Dr. Hilgendorf, Mr. D. Petrie, Mr. R. Speight, Mr. J. Stewart, Mr. K. Wilson.

Changes in the Representation.—The Secretary announced the following changes in the representation of the Government and of the incorporated societies on the Board of Governors:—

Nominated by the Government: Mr. C. A. Ewen (*vice* Mr. J. W. Joynt, resigned). Elected by incorporated societies: Dr. Hilgendorf (*vice* Dr. Farr, resigned).

The Secretary then called the roll.

The President declared the meeting open, and apologized for the absence of His Excellency the Governor, the Hon. the Minister of Internal Affairs, Mr. Martin Chapman, K.C., Professor Easterfield, Mr. C. A. Ewen, Mr. H. Hill, and Mr. John Young.

Presidential Address. The President then delivered his presidential address. (See p. 74.)

Report of the Standing Committee.—The Secretary read the report of the Standing Committee, which was adopted, as follows:—

REPORT OF THE STANDING COMMITTEE.

During the past year seven meetings of the Standing Committee of the Board have been held, the attendance being as follows: Mr. Hamilton, 6; Mr. Chapman, 4; Professor Easterfield, 6; Mr. Joynt, 3; Mr. Petrie, 2; Mr. Thomson, 2; Mr. Young, 2; Professor Benham, 1; Dr. Cockayne, 1; Mr. Stewart, 1; Mr. Wilson, 1. Dr. Chilton, Hon. Editor, was present at two meetings, at the request of the Committee.

Hector Memorial Fund.—The individual members of the Board having signified their concurrence with the request of the Wellington Hector Memorial Committee (a body acting independently of the Institute) that the Institute should assume, under certain stated conditions, the custody and management of the fund, the Standing Committee has given effect to the wishes of the Governors. The report of the Institute's Hector Memorial Committee, presented with this report, deals fully with the subject. A deed of trust will be prepared.

Hutton Memorial Fund.—The Committee of Award in Sydney has been instructed in the conditions under which an award may be made, and their recommendation will be opened later at this meeting. The Standing Committee recommends for the favourable consideration of the Board an application for a research grant from the fund.

Purchase of Back Numbers of the Transactions.—The Secretary is corresponding with the owners of certain volumes, and if negotiations are successful a number of complete sets will be available for sale.

London Agency.—The transfer of this agency to Messrs. William Wesley and Son has been completed, and the engagement existing with the previous agents satisfactorily terminated.

Publications.—The cost of the publications—Transactions, Proceedings, and Bulletins—issued last year was somewhat greater than usual, and prompts the suggestion that there should be a closer connection between the Standing Committee and the Publication Committee on the question of finance. The publication of bulletins requires to be authorized and regulated.

As before, publications have been distributed direct from Wellington to members, according to the roll kept. The matter of distribution is, however, somewhat bound up with the succeeding subject here dealt with, and the practice of distribution will not be entirely uniform until that matter is settled.

Copies of Vol. xlii of the Transactions were, in accordance with the Act, laid on the table of the House of Representatives on 6th July, 1910, and of the Legislative Council on 5th July, 1910.

The Board at the last meeting decided to bind up the Proceedings published during the year with the Transactions, but this could not be accomplished with Vol. xlii, as the limited number of Parts i, ii, and iii had been distributed. The Secretary was, however, able to obtain about a hundred complete sets of the year's Proceedings, which were bound with Vol. xlii, these copies being supplied to the leading libraries on the exchange list. The new rule will commence with Vol. xliii.

Position of Incorporated Societies.—The sub-committee which was appointed by the Standing Committee has not been able to make any report, owing to the absence from Wellington of one of the members.

British Association in Australia in 1914.—A resolution was passed at the last annual meeting of the Board, assuring the Melbourne University and the Australasian Association for the Advancement of Science of the Institute's sympathy and support in the endeavours of those bodies to induce the British Association to visit Australia. It may be possible to go further than this and invite as many of the British delegates who can to visit New Zealand. The matter is obviously one in which the Institute can only act by suggestion, and it is hoped that the Government may be induced to take part in the movement.

Resolutions having the Force of Regulations.—As resolved at the last annual meeting, the Secretary has prepared a list of the resolutions passed by the Board and Standing Committee from time to time since 1904. It is desirable that a Committee be appointed to formulate these so that they may be gazetted or printed, as may be decided.

Exchange List.—The Standing Committee has added to the list the Cambridge Philosophical Society and the New Zealand Geological Survey. Other applications are held over to await the decision of the Board.

Outlying Islands of New Zealand.—Professors Easterfield and Kirk and the Secretary were appointed a sub-committee to inquire into the conditions for leasing the outlying islands of New Zealand. A report from Professor Kirk is appended.

For the Standing Committee.

Wellington, 19th January, 1911. A. HAMILTON, President.

Committee to deal with the Australian Visit of the British Association.—It was resolved, on the motion of Professor Benham, seconded by Mr. Speight, that the President (Mr. Hamilton) and Professor Easterfield be appointed a committee to deal with the Australian visit of the British Association, with power to add to their number.

Committee to formulate Regulations passed by the Standing Committee.—It was resolved, on the motion of Mr. R. Speight, seconded by Professor Benham, that a committee, consisting of the President, the Hon. Editor, Mr. Hamilton, and Mr. Martin Chapman, K.C., consider the question of formulating and preparing for publication the regulations passed by the Standing Committee. The committee to report to the next annual meeting.

Statement of Receipts and Expenditure. The statement of receipts and expenditure, audited by the Auditor-General, was, on the motion of Mr Petrie, seconded by Dr. Hilgendorf, adopted.

STATEMENT OF RECEIPTS AND EXPENDITURE

Receipts. 1910.	£	s.	d.	*Expenditure.* 1910.	£	s.	d.
Balance brought forward ..	402	10	7	Grant to Hector Memorial Fund	20	0	0
Government grant ..	500	0	0	Secretary's salary	25	0	0
Kegan, Paul, and Co.—Balance of account	55	4	4	Travelling-expenses of Board of Governors	23	17	4
Refund of postage ..	12	0	5	Alterations to seal ..	4	15	0
Sales, "Maori Art," &c. ..	5	17	3	Insurance..	9	0	0
				Hon. Editor's petty cash ..	5	0	0
				Secretary's petty cash ..	6	0	0
				W. A. Mackay—Services ..	5	0	0
				Stationery	8	9	1
				Postage of Transactions ..	24	0	0
				Purchase back volumes Transactions	0	16	6
				Typing	5	19	6
				Catalogue for scientific literature	10	0	0
				Printing Transactions, Proceedings, and Bulletins ..	699	12	0
				Expenses Auckland meeting..	50	0	0
				Bank charges and cheque-book	0	12	0
				Balance	77	11	2
	£975	12	7		£975	12	7

Carter Bequest.—The following statement, showing the state of the Carter Bequest, was received from the Public Trustee :—

STATEMENT OF ACCOUNT, 31ST MAY, 1904, TO 31ST DECEMBER, 1910.

Cr.	£	s.	d.	*Dr.*	£	s.	d.
Balance as at 31st March, 1904	2,247	9	5	Administration expenses—Carting books	0	2	0
Shares, N.Z. Loan and Mercantile Agency Company..	0	12	0	Public Trust Office commission	0	4	5
Interest, N.Z. Loan and Mercantile Agency Company..	4	4	3	Balance	2,988	18	7
Interest, Public Trust Office	736	19	4				
	£2,989	5	0		2,989	5	0

Assets.

	£	s.	d.
Balance as above	2,988	18	7
Debenture stock, N.Z. Loan and Mercantile Agency Company (face value)	32	5	5
	£3,021	4	0

Hutton Memorial Trust Fund.—The following statement, showing the position of the Hutton Memorial Research Fund, was received from the Public Trustee :—

STATEMENT OF ACCOUNT, 3RD APRIL, 1908, TO 31ST DECEMBER, 1910.

Cr.	£ s. d.	*Dr.*	£ s. d.
Capital—		Balance	642 2 1
New Zealand Institute ..	550 0 0		
Subscription	1 1 0		
Balance forwarded by Hon. Treasurer of fund ..	19 9 1		
Interest, Public Trust Office ..	71 12 0		
	£642 2 1		£642 2 1

Position of the Incorporated Societies.—It was resolved, on the motion of Dr. Hilgendorf, seconded by Dr. Cockayne, that Mr. Martin Chapman, K.C., Mr. Hamilton, and Dr. Cockayne be a committee to consider the position of the incorporated societies.

Hutton Memorial Award.—A recommendation, dated 6th December, 1910, was received from Professors T. W. E. David, W. A. Haswell, and Mr. Maiden, the Committee of Award appointed to recommend a suitable recipient for the Hutton Medal. The committee recommended that the medal be awarded to Professor W. B. Benham for his contributions to the zoology of New Zealand.

On the motion of Dr. Cockayne, seconded by Dr. Hilgendorf, it was resolved that the report of the committee be adopted.

It was resolved that the Secretary be authorized to act with the President in getting a suitable inscription engraved on the medal.

It was resolved that the Chancellor of the University of Otago be asked to present the Hutton Medal to Professor Benham at the first public ceremonial held by the University Council.

On the motion of Mr. Speight, seconded by Dr. Hilgendorf, it was resolved that the thanks of the Institute be accorded to the committee for their assistance in making this award of the Hutton Medal.

On the motion of Dr. Hilgendorf, seconded by Dr. Cockayne, it was resolved that Professor David, Mr. Maiden, and Professor Benham be appointed a committee to make the next award of the Hutton Medal.

Hutton Fund Research Grant.—An application, dated 26th September, 1910, from Dr. C. Chilton, applying for a grant of £10 towards the cost of preparing illustrations for a revision of the New Zealand *Crustacea*, was, on the motion of Dr. Benham, seconded by Dr. Cockayne, granted.

Hector Memorial Committee Report.—The report of the Institute's Hector Memorial Committee was then read and received, together with the audited statement of the fund at the time of taking it over on 30th August, 1910. A statement by the Public Trustee showing the condition of the fund on 21st January, 1911, was also received.

REPORT.

In presenting this report your committee desires to preface its remarks by a short summary of the means which have been adopted to collect the sum in hand, how the Institute became the administrator of the fund, and under what conditions it accepted the responsibility.

Sir James Hector died in November, 1907. Committees were at once set up in the various centres with the object of collecting funds to perpetuate by some fitting

memorial the great services rendered to science and to the colony by the late gentleman. At the fifth annual meeting of the New Zealand Institute, in January, 1908, a committee of the Institute was appointed "to co-operate with the other committees already moving in the direction of collecting funds for a memorial." This committee consisted of Professor Benham, Mr. M. Chapman, Dr. Cockayne, Professor Easterfield, Messrs. T. Gill, D. Petrie, and R. Speight. The Wellington Philosophical Society elected a committee consisting of Messrs. G. V. Hudson and A. Hamilton, and the Canterbury Philosophical Institute a committee consisting of Dr. Chilton, Dr. C. C. Farr, Messrs. Speight and Waite. Committees formed outside of the Institute were the Wellington Hector Memorial Committee, consisting of Sir Robert Stout, Mr. M. Chapman, Mr. A. Crawford, Professor Easterfield, Dr. J. M. Mason, with Mr T. King as Secretary. This was the chief committee, to which the other committees remitted the funds collected by them. The Dunedin Hector Memorial Committee consisted of Professor Benham, Dr. Colquhoun, Dr. Hocken (Secretary), Professor Marshall, Professor Scott, Professor Park, and Mr G. M. Thomson. By May, 1908, the chief committee had in hand £230, the greater portion of which had been collected in Wellington Province. In July, 1908, the Standing Committee of the Institute passed the following resolution: "That Dr J. M. Mason be informed that the Standing Committee is of opinion that the several Hector Memorial Committees should issue a joint circular inviting further subscriptions to the fund, and undertaking that the final allocation of the fund shall not be decided on until the subscribers have been duly consulted upon the subject. On 4th February, 1909, a conference of the delegates from the various committees was held, and it was agreed to issue a joint circular appealing for more funds. The circular was issued on 1st March, 1909, and resulted in a considerable augmentation of the funds.

The Institute's Wellington committee was not reappointed at the sixth annual meeting in February, 1909.

Your committee was not appointed until the annual meeting in January, 1910.

On 1st March, 1910, the Government having promised the fund a pound-for-pound subsidy up to £500, the Wellington Hector Memorial Committee issued a further circular calling for additional subscriptions before 31st March. Subscriptions more than enough to enable the Government subsidy to be earned were quickly received. The subscribers were then appraised of the proposal of the Wellington Hector Memorial Committee to hand over the funds to the Institute in the following circular (dated 18th April, 1910), a copy of which was sent to every subscriber:—

Circular to Subscribers.

I have the honour to state that there is now £1,015 10s. 2d., which includes a subsidy of £500 received from the Government, standing to the credit of the fund.

The following terms under which the Hector Memorial Committee is prepared to hand over the management of the fund to the Governors of the New Zealand Institute have been approved by the committee:-

1. The fund shall be invested in such securities as are proper for the investment of trust funds.

2. The Governors shall, out of the income arising from the fund, provide an annual prize, to be called the "Hector Prize," which shall have for its object the encouragement of scientific research within New Zealand.

3 The prize shall be awarded by rotation for the following subjects: Botany, chemistry, geology, physics (including mathematics and astronomy), and zoology.

4. In each year the prize shall be awarded to that investigator who, working within the Dominion of New Zealand, shall, in the opinion of the Governors of the Institute, have done most towards the advancement of that branch of science to which the prize is in such year allotted.

5. The Governors of the Institute shall draw up regulations giving effect to the foregoing scheme, and may, if they think proper, provide for the appointment from time to time of a committee of experts to give advice in the awarding of the prize.

Whilst not wishing to lay down any hard-and-fast rule, it is the desire of the Hector Memorial Committee that the recipient of the prize devote the same towards defraying the expenses of further investigation, or of the publication of researches already completed.

Robert Stout,
On behalf of the Wellington Hector Memorial Committee.

Appointment of Committee of Award.—On the motion of Dr. Hilgendorf, seconded by Mr. K. Wilson, it was resolved that a committee be appointed to recommend the Governors of the Institute as to the award of the Hector Medal and Prize. The committee for 1911 to be the Professors of Biology of the four University Colleges and Mr. Speight. The awards to be made in the order in which the subjects are herein numbered.

Committee to obtain Hector Medal.—On the motion of Mr. Petrie, seconded by Mr. James Stewart, it was resolved that a committee, consisting of the President, Mr. Hamilton, and Professor Easterfield, be appointed to arrange for preparing the Hector Medal: the cost not to exceed £100.

Report of the Publication Committee.—The following report of the Publication Committee was then read:—

The Committee begs to report that seventy-five papers were sent in for publication in the Transactions for 1909 (*i.e.*, Vol. xlii). These were considered at a meeting held in January, 1910, immediately after the annual meeting of the Board of Governors, and, with the exception of a few that were held over for further consideration, were at once handed to the Government Printer. Sixty-three papers were published in the Transactions, Vol. xlii, two in the Proceedings for 1909, Part IV, and two as separate bulletins; one was referred back to the author for condensation, and the remainder were not recommended for publication. With regard to two of these there was some correspondence with the author, but the committee adhered to its decision, on the ground that papers that are purely controversial and add no new facts of importance to the subject discussed are not suitable for inclusion in the Transactions; moreover, fairly full abstracts of these papers appear in the Proceedings. The Transactions for the year 1909, Vol. xlii, contains vi and 642 pages and 67 plates, in addition to a very large number of figures included in the text; the fourth part of the Proceedings for 1909 extends from pages 91 to 160, and includes the lists of members, the New Zealand Institute Acts, &c., which have hitherto been given in the volume of the Transactions. The final proofs of the Transactions were corrected about the middle of May, and the volume was ready for issue early in June. The thanks of the Institute are due to the Government Printer for getting the volume out at such an early date.

A few of the papers in the Transactions are of great length, and in the opinion of the committee some of them are capable of being condensed with advantage, and it may be necessary in the future to recommend this course in a greater number of cases than has been done in the past. In some cases, again, the papers are accompanied by a large number of photographs, some of which are not absolutely necessary for the illustration of the paper. As these photographs have to be reproduced as half-tone blocks on special paper, they add very considerably to the cost of the volume, and it may be necessary for the future to restrict in some way the number of plates allowed to each paper. It is desirable whenever possible that papers should be illustrated by line drawings prepared in accordance with the instructions printed for the guidance of authors of papers. Most of these can be then incorporated as text-figures, and in many respects are preferable to separate plates.

In accordance with the instructions of the Board of Governors, the committee arranged for the publication of two of Major Broun's papers on New Zealand *Coleoptera* as separate publications under the name of "Bulletins," and it hopes that the example thus set may be taken further advantage of, and that other lengthy and important papers which for any reason cannot suitably be included in the Transactions may be published as separate bulletins. Bulletin No. 1, "New Genera and Species of *Coleoptera*," contains 78 pages, and Bulletin No. 2, "Revision of the New Zealand *Byrrhidae*," 26 pages and 1 plate. Both were issued on 30th August, 1910.

The first part of the Proceedings for 1910, amounting to 30 pages, was issued on 10th September, 1910; the manuscript of the second part was sent in to the Printer early in November, and, though delayed owing to pressure of other work in the Printing Office, it is now ready for press, and will probably be issued before the annual meeting of the Board of Governors.

For the Transactions for 1910 (Vol. xliii) sixty-five papers have been sent in. These have already been considered to some extent by the Publication Committee;

several of them have been sent on to the Government Printer for insertion in the volume, and the rest will be definitely dealt with at a subsequent meeting of the committee. Three short papers have already been printed in the Proceedings at the request of the authors, and several of the others sent in seem suitable for dealing with in the same way. The committee would, however, like to have some expression of opinion from the Board of Governors as to the policy to be adopted in future with regard to the insertion of such papers in the Proceedings. Their insertion in the Proceedings would insure more speedy publication, and would probably encourage members to present their papers at an earlier period of the year.

A considerable number of papers are still hand-written, although the instructions to authors are that the manuscripts must be typewritten unless special permission to send in written manuscripts has been given by the Editor. Some opposition has been shown to the strict interpretation of this rule. Unfortunately, in written manuscripts there is room for much difference of opinion as to what constitutes a clear manuscript, and many, though apparently clear, contain numerous technical terms which are by no means clear to those unacquainted with them, and unnecessary trouble and mistakes are thus caused. The committee is of opinion that the Editor should have the support of the Board of Governors in returning any manuscript which in his opinion is likely to give the compositor more trouble than a typewritten manuscript would do. It is desirable also that greater attention should be paid to the instructions issued for the preparation of drawings for the Transactions.

The question of the number of reprints to be supplied to each author has been brought before the notice of the committee, and after carefully considering the matter the committee recommends that, as hitherto, twenty-five should be the ordinary number supplied gratis, but, in consideration of the facts that a wide distribution of the scientific work done in the Dominion is desirable, and that reprints reach many more persons interested in a particular subject than the complete volume of the Transactions can do, the committee suggests that authors who so desire may, with the approval of the Publication Committee, be allowed fifty copies free of charge, and that additional copies, if required, be charged for at cost-price, the rate to be duly announced; the committee to have power, subject to the approval of the Board of Governors at its annual meeting, to deal with any exceptional cases that may arise.

The committee has also considered the possibility of more fully indexing the future volumes of the Transactions as they appear. There are several difficulties in the way, and the preparation of a complete index might delay the appearance of the volume, but the committee hopes that when the second part of the index to the first forty volumes, containing the titles of the papers classified according to the subjects dealt with, has appeared it may be possible to include in each volume of the Transactions a subject-index on somewhat the same plan.

For the Publication Committee.

Christchurch, 11th January, 1911. CHAS. CHILTON, Hon. Editor.

On the motion of Professor Benham, seconded by Dr. Hilgendorf, it was resolved that the report of the Publications Committee be received.

Papers to be printed in Proceedings.—On the motion of Mr. Petrie, seconded by Dr. Cockayne, it was resolved that the Board of Governors approve of the policy of printing short scientific papers in the Proceedings of the New Zealand Institute.

Instructions to Authors of Papers.—On the motion of Professor Benham, seconded by Mr. R. Speight, it was resolved that the memorandum for authors in the Transactions, section 1, be amended by the insertion of the words "for the time being" after the word "Editor"; also that the words "By order of the Board of Governors" be placed at the end of the memorandum.

Authors' Separate Copies.—On the motion of Mr. Speight, seconded by Mr. K. Wilson, it was resolved that the recommendations of the Publications Committee *re* authors' separate copies be approved, and that the authors must intimate their wishes as regards the number of copies required when sending in manuscript.

Professor Benham moved, and Mr. Speight seconded, that the rule in regard to authors' separate copies be inserted in the memorandum to authors. Carried.

Monographs and Bulletins.—On the motion of Professor Benham, seconded by Dr. Cockayne, it was resolved that a new regulation be adopted: "In addition to Proceedings and Transactions, special monographs or bulletins may be published from time to time."

Report of the Librarian.—The report of the Hon Librarian was received, as follows:—

During the past year considerable progress has been made in the arrangement of the library. Proper pigeon-holes have been provided, and labelled for the current numbers of the serial publications received from various parts of the world. This enables the parts as they arrive to be kept together in definite places. A new system of entering the parts received has also been instituted, and will enable the checking of parts received to be more easily accomplished; it also points out the missing numbers. Owing to the kindness of the Minister of Internal Affairs, a lady has been employed for two months in tying up and checking bound and unbound sets of serial publications. A list has also been prepared of the unbound volumes, showing the parts missing. From this list it will be easy to compile a list of parts to be ordered on some future occasion to complete the sets. The number of items received during the year is 859. I would draw your attention to a book which has been received, the report of the exploration of the subantarctic islands, carried out by the Philosophical Institute of Canterbury, a work which is in every way a credit to New Zealand.

Report of the Index Committee.—The report of the Index Committee was received, as follows:—

The Index Committee report that work on the index has been proceeding steadily during the year. The first part of the index is already set up, and a few copies have been printed, but the Government Printer has hitherto been unable to work off the number of impressions ordered. The second part, which gives titles and contents in a more detailed manner, has taken some considerable time, but is now ready in card form for the Printer, and the printing has been authorized by the Standing Committee. As soon as the Printer can proceed with the work it will be gone on with.

Election of Honorary Members.—The election of an honorary member in place of the late Mr. R. B. Sharp was then proceeded with.

Nominations were as follows: Captain R. H. Scott, nominated by the Auckland Institute; Sir Robert Ball, nominated by the Manawatu Philosophical Society; Dr. W. S. Bruce, nominated by the Philosophical Institute of Canterbury; Mr. W. W. Froggatt, nominated by the Wellington Philosophical Society; Sir John Murray, nominated by the Otago Institute. The ballot resulted in the election of Dr. W. S. Bruce, leader of the Scottish National Antarctic Expedition.

Bathymetrical and Biological Survey.—On the motion of Mr. Speight, seconded by Professor Benham, it was resolved that the New Zealand Institute respectfully request the Government of New Zealand to take advantage of the unique opportunity afforded by the presence of the exploring ship "Terra Nova" to carry out as complete a bathymetrical and biological survey as possible of the seas around the Auckland, Campbell, and Macquarie Islands.

Dr. Mawson's Expedition.—It was resolved, on the motion of Mr. Hamilton, seconded by Mr. Stewart, that this meeting of the Board of Governors of the New Zealand Institute desire to express their best wishes to Dr. Mawson for the success of his Antarctic expedition.

Report of Committee on Outlying Islands of New Zealand.—The report of the sub-committee appointed by the Standing Committee to report on the conditions of leasing the Auckland and other islands was read as follows:—

The Committee did not meet, but its members communicated with each other and interviewed members of the House and the Secretary to the Lands Department. Mr. Ell, M.P., laid the views of the committee before the Premier. The islands have, it is now known, been leased for £47 per annum.

Correspondence.—Correspondence was received as follows:—

From the Melbourne University (23rd February, 1910), acknowledging the resolution passed at the last annual meeting with reference to the British Association.

From Captain Scott (27th April, 1910), acknowledging the resolution of the last annual meeting with regard to antarctic soundings.

From Dr. W. S. Bruce (21st May, 1910), on the same subject.

From the Under-Secretary of Internal Affairs (17th February and 26th April, 1910), with reference to the printing of Government scientific reports.

From Nelson College, requesting to be placed on the exchange list. Approved.

Election of Officers.—The following officers for 1911 were elected: President, Mr. T. F. Cheeseman; Hon. Treasurer, Professor Easterfield; Hon. Librarian, Mr A. Hamilton; Hon. Editor, Dr. Chilton; Publication Committee, Professor Benham, Dr. Chilton, Dr. Hilgendorf, and Mr. Speight. Index Committee, Dr. Chilton, Mr. Hamilton, Professor Easterfield, Professor Benham, Mr. Speight. Mr. B. C. Aston was appointed Secretary.

Place of Meeting.—On the motion of Professor Benham, seconded by Dr. Cockayne, it was resolved that the next meeting be held at Christchurch, on the last Thursday in January, 1912.

Travelling-expenses.—On the motion of Dr. Cockayne, seconded by Mr. Stewart, it was resolved that the hotel and travelling expenses of members and the Secretary be paid by the Institute.

Reports of Incorporated Societies.—The annual reports of the Manawatu and Canterbury Societies were received.

Moved by Professor Benham, seconded by Mr. Speight, that the attention of Secretaries of societies be drawn to the resolution passed last year, and that the Governors reaffirm the need of the annual report and balance-sheet of each branch of the Institute being forwarded to the Secretary of the New Zealand Institute before the 31st December in each year, for presentation to the annual meeting.

Votes of Thanks.—On the motion of Professor Benham, seconded by Mr. Wilson, it was resolved that a special vote of thanks be forwarded to Dr. Chilton for his work as Hon. Editor.

A vote of thanks to the Auckland Institute for the use of the Museum Library was carried.

Confirmed.

27th January, 1911. A. Hamilton, President.

PRESIDENTIAL ADDRESS.

The following is the presidential address delivered at the annual meeting of the Board of Governors of the New Zealand Institute at Auckland, 26th January, 1911, by A. Hamilton, Director, Dominion Museum:—

Gentlemen of the Board of Governors,—It is my duty to lay before you a few remarks relating to the progress of the work of the Institute during the last year, and to supplement in some cases the items which you will find in the annual report of the Board of Governors and the balance-sheet.

In accordance with the resolution of the Board passed last year, the Secretary has drawn up a list of the resolutions of the Standing Committee which have the force of regulations, and these are submitted for the purpose of being put into such form as may be required to bring them into line with the regulations originally gazetted. As I have said before, I think it is our duty to have these duly printed and set forth for the information of members so long as they stand as valid and operative regulations of the Board of Governors. I have suggested that instead of their being dealt with seriatim in this meeting they should be referred to a small committee, who could report later on to the Council, and that we should consider the report of the committee as a whole.

In the report of the Publication Committee you will find a good many practical suggestions for the improvement of the Transactions. It is a matter which requires constant attention, and although many improvements have been brought about within the last few years, still much might be done with advantage, especially in the way of condensing a good deal of the matter which is now printed in full. The question of the expense of publishing is also one which will require very careful consideration, as the publication of Proceedings quarterly increases the total annual cost of publication.

When in Australia recently I noticed that there is also a movement there in the direction of co-ordinating the serial publications taken by the various bodies, and that an effort is being made to avoid the duplication of necessary and expensive works in the collection. The same movement is being initiated in Wellington, and the various libraries in that city have agreed to a systematic and mutual co-operation in the procuring of magazines, and have agreed to render them available to all students under certain conditions. By this means a certain amount has been set free for expenditure in magazines not hitherto taken. There are still several important serial publications which are not taken by any branch of the Institute or by any public library in New Zealand, and I think it would be within the province of the Institute to ascertain which of these are most necessary and desirable, and to subscribe for them for the library of the Institute, where they would be at the service of students generally. I think also that it would be to our advantage to circulate within the year, if possible in the first part of the Proceedings, a full list of the periodicals received by the societies, universities, parliamentary and public libraries, and that the list should indicate how far the back volumes are available. I do not propose that in the list any of the regular publications of learned societies, public institutions, and museums should be included, but a separate list might be published quarterly of these. It is true that all the universities, colleges, and public libraries have not hitherto been asked to agree to render their serial publications available under certain conditions, but I feel sure that we are approaching a time when universities and public institutions will do more in this direction than they have done. In the Librarian's report the necessity is pointed out for a Librarian who can give some time to library work and cataloguing. I must not omit to mention that the Hon. the Minister of Internal Affairs consented to the employment of a lady for library work for two months. During that time lists were prepared showing the completeness or otherwise of the most valuable serial publications, and from these lists the missing parts can be ordered and procured if possible.

A sum of money has been collected and placed in the hands of the Institute for the purpose of providing a memorial medal and prize in memory of the late Sir James Hector, who devoted so many years of his life to the furtherance of the interests of the Institute. This year, too, the Institute is bringing into operation the memorial fund raised in honour of the late Captain Hutton, whose researches laid such a good foundation in a number of branches of natural history. There is also an application for a grant from the fund in aid of research, which will be submitted for your consideration.

It is pleasing to me to be at the inception of these funds and to have a small part in the commencement of their work. Apart from worthily commemorating the friends whom we have lost and keeping their memory alive, there is satisfaction in knowing that at last we have some funds (which are, however, but small) which may be devoted to the advancement of research and of assistance to those engaged in research. Although we cannot yet compare with scientific institutions in other countries, still we have a beginning, and in these matters an actual start is a matter of importance. With careful administration the results obtained frequently lead to the establishment of other funds, and matters then progress much more easily. In Australia it is to the munificence of private individuals that science has fellowships which may be awarded for research work in connection with societies. The value of these fellowships is quite considerable, and they are found to be useful and productive of good work.

We have this year seen another well-equipped Antarctic expedition leave these shores under the command of Captain Scott. On behalf of the Institute, I wished Captain Scott success and a safe return.

In Sydney at a recent meeting of the Australasian Association for the Advancement of Science I had the pleasure of attending an enthusiastic meeting of the General Council, when a sum of £1,000 was voted from the funds of the association towards purely Australasian explorations, which have been organized for the purpose of antarctic research under the leadership of Dr. Mawson. New Zealand is not within the political bounds of the Commonwealth of Australia, but nevertheless we must feel as a scientific body deep interest in any scientific work within the Antarctic area, and I think perhaps more especially in Dr. Mawson's expedition, as they intend exploring, if possible, a particular part of the southern continent within which the meteorological observations that will be made will be of the greatest possible interest to New Zealand and the shipping of the surrounding waters. The commercial advantages which are hoped for may or may not be realized, but the scientific data in meteorology will certainly be of interest and value. It is therefore, I think, right and proper that at this our meeting we should send to Dr. Mawson our best wishes for his success and safe return of his expedition.

At the Australasian meeting several matters of interest to New Zealand were dealt with, and several recommendations were passed by the committee which are of interest to scientists in New Zealand. One of them relates to the desirability of the New Zealand Government taking steps to arrange for the description of the New Zealand fossils collected by the New Zealand geological surveys. This resolution also refers to a previous one which had been communicated to the New Zealand Government during the Dunedin meeting. It recognized that certain steps had been taken to prepare the mass of fossils for description, and hoped that the further and more important step would be taken of having them properly described and published.

It is with considerable satisfaction that I notice that the Animals Protection Act has been so altered by the last Parliament as to declare all indigenous birds protected. This is a matter which I have been advocating for some considerable time as being the best way to carry out protective measures. With this principle as a basis it is easy to exempt from protection for any time that is desirable, or in any place, birds which may be proved to be a real nuisance in destroying fish or injuring sheep. No doubt the steps taken by the Philosophical Institute of Canterbury assisted in bringing about the present result. In other countries where this principle has been adopted it has been found to work satisfactorily, and I have no doubt that eventually this principle will be adopted by all countries which find it necessary to have protective legislation on their statute-books. I interviewed members of the House on behalf of the Institute with a view to making representations to the Government as to leasing the Auckland Islands. It is true that we recognize with much pleasure the reservation of Adams Island as a sanctuary for the native flora of that part, but the leasing of the main island must be regarded with regret in view of the small amount of revenue which is thereby obtained. The Standing Committee considered the question of themselves applying for the lease, but it was found that matters had gone too far.

There is one subject that I should like, in this my last opportunity of addressing you from the presidential chair, to bring forward. Once every year we have a general meeting of the members of this Board. Owing to geographical considerations it is sometimes difficult to get a full meeting. Those who do attend the meeting have to receive the annual report of the work that has been done by the Standing Committee, which is practically the executive of the Board. As a rule, it is best to have an executive consisting of a small number of the members, and I have no

fault to find with this part of the arrangements, but the work so far of the Board at its annual meeting, and of the executive at their more frequent meetings, is confined to matters relating to the minor affairs of the Institute and its financial arrangements. At the general meeting the annual report and the general report and balance-sheet are submitted, and if necessary there is then an opportunity for discussion. Hitherto any time that we have had at the general meetings has been devoted to the reading and criticizing and passing of these reports and the election of the officers. It is true much has been done since the passing of the new Act in the matter of initiating the new system of dealing with the affairs of the Institute, and that good work has been done in this direction, but I do not think we should consider we have done hitherto all that we should have done or that we ought to do at the annual meeting of the Governors of this Institute. This Institute occupies a position which is likely to remain unique, inasmuch as it is and will be, if properly administered, the sole scientific body in the Dominion of New Zealand. Here I may again remind you that under the new Act the various local societies which are working now in the chief centres of New Zealand are not, as aforetime, affiliated to the Institute, but they are the Institute, though they may have an independent existence: under the regulations they are the Institute. It seems to me, however, that at our annual meeting we should not meet expecting only to receive the reports, make suggestions on them, pass the annual accounts, and confer prizes and medals, but that we should look forward to a time when the Board of Governors will be recognized as the central authority for the co-ordination of official and private inquiry into scientific matters in the Dominion of New Zealand. It is well known that in our great Empire of India the Government constituted in 1902 a Board of Scientific Advice for India, which originally consisted of the heads of the Meteorological, Geological, Botanical, Forest, Survey, Agricultural, and Veterinary Departments. At the same time they intimated their intention to invite from time to time to serve upon it other scientific officers in the service of the Imperial and Provincial Governments whose special attainments might render their assistance desirable. The Board was declared to be a central authority for the co-ordination of official inquiry, its object being to insure that the work of research is distributed to the best advantage, that each investigator confines his researches to the subject with which he is most capable of dealing, and that energy is not dissipated by the useless duplication of inquiries or misdirected by a lack of inter-departmental co-operation. It was also hoped that while the claims of abstract science would continue to be recognized in the work of the scientific departments, the Board's advice would aid the Government of India in prosecuting practical research into those questions of economic or applied science on the solution of which the progressive prosperity of the country, especially as regards its agricultural and industrial development, so largely depends. The Board advises generally upon the operations of the departments, with due attention to the economic side of their work, and serves as a reference on all matters connected with the organization of scientific inquiry in India. It annually discusses the proposals of each departmental head in regard to the programme of investigation in his department, and in cases where inter-departmental co-operation is necessary it advises as to the lines on which mutual assistance should be given and the department to which the inquiry should primarily appertain. It submits annually to the Government a general programme of research, embodying the proposals of the departmental heads in so far as its subjects are to be exclusively dealt with in one department, and its own proposals in cases where two or more departments are to co-operate, and at the end of the year it presents a brief review of the results obtained during the year in all lines of scientific investigation controlled by its members.

Although I do not consider that this or any other similar scheme could be adopted *in toto*, yet I hold that the principle is a good one. Hitherto in matters of scientific research, public and private, we have been largely opportunists, possibly by force of circumstances; but I do not think it would require much argument to convince you that co-operation and scientific organization of the various branches of research which are so largely interdependent on each other would be desirable and economical, and that it would be a great advantage to arrange such investigation on lines by which mutual assistance could be given. Take the universities, for instance: for some time past research has been carried on, notwithstanding disabilities of various kinds—such as want of necessary literature and other disabilities—in the biological laboratories of the University Colleges; a number of papers showing a considerable amount of hard work have been produced, and many of them printed in our Transactions. It would seem that more scientific good would result from intelligent co-operation in the choice of subjects for investigation, also in

private work, but an annual conference of workers would stimulate research and eventually its methods and aims. The geographical difficulties to which I before alluded to, which keep us separated by wide intervals during the year, are in one respect advantageous, as they give opportunities for detailed study over areas of the Dominion which vary much in their natural-history productions. By the Act of incorporation we are given a great opportunity, and we should see to it that we break new ground well in the forefront of our onward track.

The body of research work done is much larger than those unacquainted with it might suppose, and much of it is of excellent quality within certain narrow limits. Those limits are in part inevitable and in part justifiable. So far there has been little endowment of research, and nearly all the work is done in a necessarily scrappy fashion by men in professional employment. The man who can give his life for an idea is unknown among us, and, following the line of least resistance, we are apt to do the work nearest us with no eagle eye on ultimate issues. Once we are made to feel the influence of science, not merely on the accelerating progress of the State, but on the world of ideas, of morals, and of emotion, we may expect endowment to be much more frequent than it has been in the past. Men could be found to do the work if the opportunity was present. Undoubtedly the best plan is to provide research scholarships for young graduates, tenable for short terms: from them in time will come the born investigator—the one in a thousand—who should be permanently kept at work by private endowment or by the State.

AUCKLAND INSTITUTE.

Eighth Meeting: *22nd November, 1910.*

Mr. E. V. Miller, Vice-President, in the chair.

Papers.—1. "Maori Rock-engravings in the Kaipara District," by R. Buddle.

2. "Maori Methods of Shark-fishing and Pigeon-snaring Fifty Years ago," by R. H. Matthews.

3. "Descriptions of New Genera and Species of *Coleoptera*," by Major T. Broun.

4. "Additions to the Coleopterous Fauna of the Chatham Islands," by Major T. Broun.

5. "Descriptions of New Native Phanerogams," by D. Petrie, M.A.

6. "Contributions to a Knowledge of the New Zealand Flora: No. 4," by T. F. Cheeseman, F.L.S.

7. "On some Recently Discovered Additions to the New Zealand Flora," by T. F. Cheeseman, F.L.S.

8. "On the Flora of the Mangonui County," by H. Carse.

9. "The Economic Aspect of the Sugar-beet Industry in New Zealand," by S. Gray.

The last paper called forth a lengthy discussion, in which the Chairman, Mr. Bagnall, Mr. H. B. Morton, Mr. J. A. Pond, Professor Segar, and others took part. Most of the speakers supported the contention of the author, which was to the effect that it would be an economic mistake for the Dominion to embark in the production of beet-root sugar, which was an industry hardly likely to succeed against the competition of cane-sugar, unless a bonus was granted, or unless import duties were levied on cane-sugar.

Ninth Meeting: *6th February, 1911.*

Dr. R. Briffault, President, in the chair.

Lecture.—Professor E. W. Skeats, D.Sc., F.G.S., Professor of Geology and Mining in the University of Melbourne, delivered a lecture, illustrated with lime-light transparencies, on the "Relation of Scenery to Geology."

The lecture was an attempt to show how far the scenery of any country was dependent on its geological structure and previous geological history.

Annual Meeting: *27th February, 1911.*

Dr. R. Briffault, President, in the chair.

Annual Report.—The annual report and audited financial statement were read to the meeting, and ordered to be printed and circulated amongst the members.

Report of the Council.

As provided for by the constitution of the society, the Council have now to present to the members their forty-third annual report on the financial and general condition of the Institute, and the progress it has made during the year.

Members.—It is satisfactory to announce that thirty-two new members have been elected since the date of the last annual meeting—a number considerably above the average. On the other hand, fourteen names have been removed from the roll—three from death, seven from resignation, and four from non-payment of subscription for more than two consecutive years. There is thus a net increase of eighteen, the total number on the roll at the present time being 204, of whom twelve are life members and 192 annual subscribers. The Council trust that the increase in the membership will be maintained in coming years. They would point out that the chief aim of the Institute—the maintenance of a free public museum for the instruction and recreation of the people of Auckland—is one which appeals to all classes and which should command a liberal amount of support.

Finance.—The detailed balance-sheets will make the financial position of the Institute intelligible to all who inspect them, but it may be useful to give a brief synopsis here. The total revenue credited to the Working Account, excluding the balance in hand at the commencement of the year, has been £1,170 11s. Last year the amount was £1,195 0s. 9d., so that there has been a decrease of £24 9s. 9d. Examining the chief heads of the balance-sheet, it will be seen that the receipts from the invested funds of the Costley Bequest have been £402 18s. 8d., as against £386 15s. for the previous year. The Museum Endowment has yielded £424 15s. 2d., the amount for 1909-10 being £502 8s. But the amounts for that period have swollen through the payment of some arrears of rent and interest which should have been credited during the previous twelve months. The members' subscriptions have realized £191 2s., showing an increase of £17 17s. The total expenditure has been larger than usual, amounting to £1,283 9s., as against £1,209 11s. 8d. for 1909–10. The increase is principally due to three items—the enlarged expenditure over the library caused by the publication of the library catalogue (presently to be referred to), the cost of certain show-cases indispensably required in the Museum, and some unavoidable repairs to the roof and other portions of the building. The balance in hand at the present time amounts to £144 1s. 11d. There are no changes of importance respecting the invested funds of the Institute, the total amount of which, £16,379 4s. 3d., only very slightly exceeds that announced last year.

Meetings.—Nine meetings have been held during the year, at which the following lectures or papers were read :—

1. "Halley's Comet," by Professor H. W. Segar.
2. Presidential address, "The Nature of Life," by Dr. R. Briffault
3. "Ferro-concrete Structures," by S. E. Lamb, B.Sc.
4. "Wireless Telephony," by A. Wyllie, M.I.C.E.
5. "The Ultra-microscope and what it reveals," by E. V. Miller.
6. "The Effects of the Disappearance of the New Zealand Bush," by Archdeacon Walsh.
7. "Huxley : a Criticism and an Appreciation," by the Rev. D. D. Scott.
8. "The Relation of Scenery to Geology," by Professor E. W. Skeats, D.Sc.

Also nine papers on various scientific subjects (see proceedings of Eighth Meeting *supra*, p. 78).

Most of the above papers have been forwarded to the New Zealand Institute, with the view of publication in the next volume of Transactions. Volume xlii of the Transactions, containing the papers read before the incorporated societies during the year 1909, has been issued and distributed among the members.

In last year's report the Council hinted that it would probably be necessary to make temporary arrangements for holding the meetings outside the Museum buildings in the future. The selection of a hall was by no means an easy task, but after full consideration it was decided to engage St. Andrew's Hall, in Symonds Street, for the purpose. On the whole, the choice has proved satisfactory, although it is much to be regretted that want of space should prevent the meetings from being held within the Institute's own buildings. The Council trust that this end may be achieved at no distant date.

Museum.—With the exception of a few days required for cleaning and rearrangement, the Museum has been open to the public daily throughout the year. The hours of admission have been, as in former years, from 10 a.m. to 5 p.m. on week-days, and from 2 p.m. to 5 p.m. on Sundays. The register kept by the janitor on Sundays shows that 17,311 visitors entered the building on that day, being an average of 333 for each Sunday. The greatest attendance was 599 on 31st July; the smallest, 65 on 8th May. On the seven chief holidays of the year the number of visitors was 2,993, or an average of 427. The number of visitors on ordinary week-days is certainly not less than 180, which would make a total of 55,080. Adding to this number the attendance on Sundays and holidays, we have 75,384

as the approximate total number of visitors during the whole year. This is only very slightly under the estimated attendance for the previous year, which was 75,957.

The progress made by the Museum during the year must be considered as satisfactory. Many important additions have been received, and most of these have been placed on exhibition. Much time and labour have been devoted to the task of preparing and mounting the specimens intended for public view: and through the efforts of Mr. Griffin, who has charge of this branch of the society's work, the general appearance of the collections, and their value for educational purposes, have been much enhanced.

In last year's report it was stated that a commencement had been made in the formation of a collection of New Zealand food-fishes. This object has been kept steadily in view, and, in order to obtain material, special expeditions have been made to the Bay of Islands, the Great Barrier Island, and to various parts of the Hauraki Gulf. Altogether sixty-eight specimens have been carefully mounted and painted from life, and it is intended to materially extend the collection during the coming autumn. Another novel addition consists in the preparation of a series of gelatine casts of the tuatara lizard and other New Zealand Reptilia. Among other work performed during the year may be mentioned the complete rearrangement of the collection of New Zealand birds, and the addition thereto of several freshly prepared specimens.

Other noteworthy additions are as follows: A fine specimen of the rare Haast's kiwi, obtained through the good offices of the Tourist Department; a very fair example of the white crane, now nearly extinct in New Zealand, purchased from Mr W. Townson; a specimen of *Sula fusca*, shot at the Bay of Islands; and an example of the widely spread water-snake *Hydrus platurus*, stranded on the ocean-beach west of Helensville. This last specimen came ashore alive, and was promptly forwarded to the Museum by the finder, Mr. E. Smith. Mention must also be made of three fine specimens of the robber-crab *Birgus latro*), obtained on Caroline Island, north of Tahiti, and presented by Mr. J. L. Young. These have been mounted so as to show the tree-climbing habits of the species, a peculiarity hardly known in other forms of the *Crustacea*.

Another important addition consists of a large and varied collection of butterflies, presented by Mr. H. Dobbie. The greater portion of the collection was formed by Mr. Dobbie during a lengthened visit made to tropical South Africa a few years ago; another part consists of species forwarded by the British Museum to Mr. Dobbie in exchange for specimens from South Africa. To these have been added a considerable number of species obtained by the Museum from various sources during the last eight or ten years, including species from China, Indo-Malaya, New Guinea, &c. It should be mentioned that the show-case in which the collection is displayed has been presented to the Museum by the subscriptions of several Auckland gentlemen.

A considerable number of improvements have been made in the arrangement of the Maori collections. Among the objects which have been altogether rearranged are those which can be described as fishing-materials, such as fish-hooks, fishing-lines, fishing-weights, nets, mussel-dredges, eel-baskets, &c. The collection of canoe-balers has been remounted, as also a good series of bird-snares, &c. Among the new additions the following may be particularized: A large river-canoe, obtained by purchase in the Upper Thames district: two canoe-memorials from the Lower Waikato; a series of carvings in pumice-stone found near the north end of Lake Rotoehu, presented by Mr. V. J. Blake: two remarkable carvings in pumice, presented by Mr. W. J. Benner and Mr. J. Griffin respectively; a large and highly polished stone axe found near Ngaruawahia, forwarded by Mr. H. Tarver; an elaborately carved step of a *ko* or spade, some wooden flax-beaters, a carved fork, and various other articles presented by Mr. G. Graham; a very interesting series of seventeen articles in greenstone, ordinary stone, and bone, purchased from Mr. W. Townson.

In foreign ethnology by far the most valuable addition is a series of over five hundred articles from Japan, including a few from China, deposited by Mr. H. S. Dudley. The collection includes many fine bronzes, swords, daggers, and other articles in metal; numerous carvings in wood and ivory; many varied specimens of pottery, porcelain, and cloisonné; specimens of lacquer-work; of silks embroidered with gold and silver; and other articles too numerous to mention. This collection is the result of Mr. Dudley's personal efforts during three visits to Japan, and the specimens have been carefully and judiciously selected. The Museum was so poorly supplied with ethnographical material from China and Japan that Mr. Dudley's deposit was a most welcome addition, and its presence in the Museum has attracted great numbers of visitors.

Library.—The Mackelvie Library Bequest has yielded its usual revenue during the year, and this, in compliance with the terms of the bequest, has been expended solely in the purchase of books. Two consignments have been obtained from London, numbering about 125 volumes. In addition to the purchase of books, a large expenditure has been incurred in binding scientific journals, publications of societies, &c., about eighty-five volumes having been added to the library from that source alone. The usual presentations and exchanges have been received from foreign societies, in addition to several donations from private individuals.

In last year's report it was stated that the Council had decided to proceed with the preparation of a printed catalogue of the library. The work has been completed during the year, and copies of the catalogue can now be obtained from the Secretary at the price of 5s. each. The usefulness of the catalogue cannot be questioned, but so far the sale of copies has hardly equalled the anticipations of the Council. It should be mentioned that purchasers of the catalogue will be supplied each year with a printed list of additions to the library.

In concluding the report, the Council have once more to thank the members for the assistance they have given in furthering the objects of the society. They have also to express their gratification at the countenance and sympathy evinced by the general public, and particularly at the increasing number of donations to the Museum forwarded by country residents. In many respects the steady progress of the Institute and Museum is a matter for congratulation. It is true that the slender means available will not permit of rapid or startling advances, but the Council can fairly claim that in carrying out the work of maintaining a free public Museum and scientific library they are discharging a duty of no small importance, and one which entitles them to the sympathetic assistance of the whole community.

Election of Officers for 1911.—*President*—J. H. Upton; *Vice-Presidents*—Dr. R. Briffault, Professor C. W. Egerton; *Council*—L. J. Bagnall, Professor F. D. Brown, E. V. Miller, T. Peacock, J. Reid, Dr. E. Roberton, Professor H. W. Segar, J. Stewart, Professor A. P. W. Thomas; *Trustees*—Professor F. D. Brown, T. Peacock, J. Reid, J. Stewart, J. H. Upton; *Secretary and Curator*—T. F. Cheeseman; *Auditor*—S. Gray.

On the motion of Mr. T. Peacock, a special vote of thanks was passed to the retiring auditor, Mr. W. Gorrie, who had acted in that capacity for eighteen years.

A vote of thanks to the retiring President, Dr. R. Briffault, was also passed, also to Mr. T. F. Cheeseman, with congratulations on his election as President of the New Zealand Institute.

WELLINGTON PHILOSOPHICAL SOCIETY.

SIXTH (ANNUAL GENERAL) MEETING: *5th October, 1910.*

Mr. A. Hamilton, President, in the chair.

The annual general meeting was held in the Dominion Museum; Mr. A. Hamilton, President, was in the chair, and about forty members and friends were present.

New Members.—Mr. H. R. Tolley, Mr. J. Thomson, B.E., M.Inst.C.E., Mr. R. W. Holmes, M.Inst.C.E., Mr. H. Sladden, Miss J. A. Wilson, Rev. Dr. Kennedy, F.R.A.S., Mr. D. McKenzie, Mr. H. Oram, M.A., LL.B., Mr. F. M. Renner, M.A., Mr. P. Levi, M.A., Dr. J. M. Mason, Mr. H. H. Tombs, Mr. J. B. Robertson, Mr. J. Mackenzie.

The Council's report for the session, and a statement of the receipts and expenditure, were read, and, on the motion of Mr. Thomas King, seconded by Mr. P. G. Morgan, both were duly adopted. The report was as follows:—

ANNUAL REPORT.

The session opened on the 4th May with an inaugural address by the President, Mr. A. Hamilton, in which he referred to the work done in opening up the Tararuas for investigation by naturalists, and urged the establishment of a mountain observatory on Mount Hector.

During the session no less than twenty-nine papers have been read, and a number of interesting exhibits have been laid on the table.

In addition to the six ordinary meetings three special meetings have been held. At the first one Professor Bickerton, of Christchurch, delivered a lecture on the astronomical importance of the theory of the third body*; at the second one Mr. T. Buckley, Chief Electrician of the Telegraph Department, delivered a lecture on wireless telegraphy, illustrated by a number of experiments; while the third special meeting was held to constitute the Astronomical Section.

A feature of the session has been the establishment of the Astronomical Section of the society, formed for the promotion of the study of astronomical subjects generally and the establishment of an observatory in or about Wellington.

The section has already held one meeting, when Dr. Kennedy, F.R.A.S., delivered a lecture on astronomy, illustrated by a series of lantern-slides, in the Concert Chamber of the Town Hall, the use of which was kindly granted by the City Council.

The joint-library scheme has been advanced another step by the Council allowing Victoria College students and other interested persons the privilege of consulting books in the library under suitable regulations.

Captain Scott's expedition to the Antarctic: As this expedition will furnish an excellent opportunity of obtaining tidal records at the Antarctic, the Council waited on the Minister of Marine and proposed that the Government should authorize the society to expend a sum not exceeding £20 on purchasing an automatic tide-gauge to be placed in Captain Scott's care. The suggested gauge would be similar to, though smaller than, the Wellington tide-gauge. The observations would be of great use to the recently established Tidal Survey of the Dominion. The Minister, while recognizing the great value of these observations, considered it highly probable that Captain Scott is already provided with a suitable tide-gauge, but if he is not so equipped, the Government will be prepared to supply the necessary instrument if Captain Scott will undertake the work and furnish the Government with a copy of his observations.

* At a subsequent meeting of the Council the sum of £10 was voted to the Bickerton Fund for the purpose of enabling the Professor's astronomical theory to be put before the Astronomical Societies for criticism. The Council, however, do not desire to express any opinion on the theory, but wish him every success in his efforts to obtain a full hearing for it.

The important subject of tidal observations at the outlying islands has also received consideration, and the Council is now endeavouring to obtain the services of an observer at the Chatham Islands.

Since the last annual meeting twenty-two new members have been elected, three have resigned, two have died, and one has been struck off the roll for non-payment of subscription. The total number on the roll is now 132, including five life members and one honorary member.

A statement of the receipts and expenditure for the year ended 30th September, duly audited, shows that, inclusive of the balance brought forward from last year (£39 9s. 8d.), the receipts amounted to £163 8s. 2d., and the total expenditure was £108 0s. 9d., leaving a credit balance of £55 7s. 5d. The Research Fund, on fixed deposit with the Bank of New Zealand, now amounts to £48 1s. 4d., making a total sum in hand of £103 8s. 9d.

Alteration of Rules.—In accordance with Rule No. 26, the resolution of the Council of 27th July, 1910, to rescind the following paragraph at the end of Rule No. 26, was submitted for confirmation:—"Resolution for by-law, adopted by the society 7th April, 1868: That one-sixth part of the annual income of the society be contributed towards the extension and maintenance of the museum and library of the New Zealand Institute." On the motion of Mr. Thomas King, seconded by Mr. P. G. Morgan, the Council's resolution was confirmed.

Papers.—1. "The Post-Tertiary Geological History of the Ohau River and of the Adjacent Coastal Plain," by G. Leslie Adkin.

2. "The Igneous Rocks of the Waihi Goldfield," by Percy G. Morgan, M.A.

3. "A Note on the Structure of the Southern Alps," by Percy G. Morgan, M.A.

4. "Notes on Actinians from the Kermadecs," by F. G. A. Stuckey, M.A.

5. "Notes on Tunicates from the Kermadecs," by F. G. A. Stuckey, M.A.

6. "The First Noted Occurrence of Pentathionic Acid in Mineral Waters," by Dr. J. S. Maclaurin.

7. "The Harmonic Analysis of Tidal Observations," by C. E. Adams, M.Sc., F.R.A.S.

ABSTRACT.

The paper gives a complete example of Dr. Börgen's method* of harmonic analysis of tidal observations. The observations submitted to analysis are those given in the Great Trigonometrical Survey of India, Vol. xvi, and are hourly observations for Bombay for the year 1884. The hourly observations were first summed continuously throughout the year, and were cut down to one decimal of a foot and written out in a list of sums, as under:—

	H.	H.	H.		H.	H.
Day	0	1	2	. . .	22	23
0	135	130	91	. . .	142	161
1	322	284	213	. . .	260	308
2	488	454	365	. . .	349	429
...	...	...	...	. . .	...	...
367	43697	43809	41081	. . .	40413	42754
368	43834	43194	41160	. . .	40544	42896

The figures in the list are given in tenths of a foot. The method consists in selecting from the list the particular days that will give the best values of the tide sought, at the same time eliminating the effect of the S. tides and reducing the effect of the other tides as much as possible.

* Ueber eine neue Methode, die harmonischen Konstanten der Gezeiten abzuleiten. Von Admiralitatsrath Prof. Dr. Börgen. Annalen der Hydrographie und Maritimen Meteorologie, Juni, Juli, August, 1894.

Example for K_2 tide :—

If the following lines are used from the list :—

$$(185 - 97) ; (96 - 8)$$

—*i.e.*, equal intervals of 88 days—then the S. tides are completely eliminated, and the maximum value is obtained for the K_2 tide.

If the following lines are used (when the observations extend over a year), a further value is obtained :—

$$(362 - 274) : (273 - 185).$$

The selection of these lines and the sums from the list is shown in detail on the schedule, giving the 24 values of Dt, which are subjected to analysis. St and $S_6h + t$ are next formed, and then Δt. The calculation of the values of

$F_k' = \sum_0^5 \Delta_t \sin (9 + t) i_k$ and $G_k' = \sum_0^5 \Delta_t \cos (9 + t) i_k$ is most readily done on the

calculating-machine. The corrections due to the tides M_2, N, L, V, T, and R are calculated and applied to F and G. The rest of the calculation is shown on the schedule, where comparisons with the results in Vol. xvi of the Indian Survey (p. 296) are also given, the differences in the values of κ and R being 4·745° and 0·0020 ft.

Reference must be made to Dr. Borgen's paper for details of the method. The whole of the calculation is, however, given in full, and the brevity of the method will be appreciated by those who have had experience in the analysis of tidal observations.

For the other tides more lines from the list of sums are used ; but even then the labour of analysing a year's observations is estimated by Dr. Börgen to be about a tenth of the labour of the method proposed by Sir W. Thomson and Mr. Roberts, and to be about a third or a half of that of Darwin's abacus.

8. "The Time-control of the Wellington Tide-gauge," by C. E. Adams, M.Sc., F.R.A.S.

Abstract.

Owing to the situation of the Wellington tide-gauge* in one of the cargo-sheds on the wharf, it was considered desirable to have an independent control of the time, for owing to the vibrations of the shed the gauge-clock's rate has been found to vary irregularly, and the clock has occasionally been stopped by the vibrations. A time-control has been attached to the pencil-carriage, carrying a small plunger in circuit with the Observatory clock, and by means of this plunger a mark is made on the record-paper every mean solar hour. The distance between the pencil and the plunger is 1·14 in., the line joining them being always at right angles to the axis of the cylinder. It is found that the tide-gauge clock runs regularly while undisturbed by cargo-shifting, but that at other times its rate is affected by the vibrations of the shed.

9. "Further Contributions to the Chemistry of the Flora of New Zealand," by Professor Easterfield.

10. "Notes on the *Lepidoptera* added to the Collection in the Dominion Museum during the Season 1909–10," by H. Hamilton, A.O.S.M.

11. "Some Recent Discoveries of Moa-bones," by A. Hamilton, F.L.S.

12. "Notes on Some Strange and Rare Fishes," by A. Hamilton, F.L.S.

13. "Sponges from the Kermadecs," by Professor Kirk.

14. "Chemistry and Toxicology of New Zealand Plants," by B. C. Aston, F.C.S.

15. "List of Indigenous Phanerogamic Plants of the Wellington Province," by B. C. Aston, F.C.S.

16. "A Further Botanical Exploration of the Tararuas," by B. C. Aston, F.C.S.

17. "Notes and Descriptions of New Zealand *Lepidoptera*," by E. Meyrick, B.A., F.R.S., F.Z.S.

* Trans. N.Z. Inst., Vol. xli, p. 407.

Exhibits.—Mr. Phillips Turner exhibited a crested *Polypodium Cunninghami*, a very interesting specimen of rare occurrence.

The President exhibited a number of cases of foreign butterflies from the museum collection.

Astronomical Section.—The President of the Astronomical Section, Mr. C. P. Powles, announced that the funds in hand amounted to £34, being the proceeds of the Rev. Dr. Kennedy's lecture and private donations; and that the first meeting of the section will be held on 11th October.

Election of Officers for 1911.—The following officers were elected for 1911: *President*—Mr. G. V. Hudson, F.E.S.; *Vice-Presidents*—Mr. Thomas King, F.R.A.S., Dr. C. Munro Hector; *Council*—Mr. Martin Chapman, K.C., Professor H. B. Kirk, Mr. F. G. A. Stuckey, M.A., Professor D. K. Picken, Rev. Dr. Kennedy, F.R.A.S., Professor T. H. Easterfield, Mr. A. Hamilton, F.L.S.; *Secretary and Treasurer*—Mr. C. E. Adams, M.Sc., F.R.A.S.; *Librarian*—Miss J. A. Wilson; *Auditor*—Mr. E. R. Dymock, A.I.A.N.Z.

ASTRONOMICAL SECTION.

Meeting, 22nd August, 1910.

Dr. C. Munro Hector in the chair.

The section was formed with the following objects: To promote the study of astronomical subjects generally, and to secure the establishment of an observatory in or near Wellington.

The following officers were elected: *President and Treasurer*—Mr C. P. Powles; *Council*—Mr. C. E. Adams, M.Sc., F.R.A.S., Dr. C. Munro Hector, Rev. Dr. Kennedy, F.R.A.S., Professor Picken, Mr. G. Hogben, M.A.; *Hon. Secretary*—Mr. A. C. Gifford, M.A.

A fund in aid of the proposed observatory was opened by subscription.

Meeting, 29th September, 1910.

Mr. J. P. Firth in the chair.

The Rev. Dr. Kennedy, F.R.A.S., gave an illustrated popular lecture on astronomy, in aid of the Observatory Fund, in the Concert Chamber of the Town Hall, which was granted free by the City Council.

Meeting, 11th October, 1910.

Mr. C. P. Powles, President, in the chair.

The rules of the section, which had been drawn up by the Council, were read and confirmed.

Mr. C. P. Powles then gave his presidential address on astronomy, which was illustrated with a fine collection of lantern-slides.

PHILOSOPHICAL INSTITUTE OF CANTERBURY.

EIGHTH MEETING: *2nd November, 1910.*

Present: Mr. R. M. Laing, President, in the chair, and sixty others.

New Members.—Messrs. A. G. Marshall, N. C. Staveley, G. W. Bishop, and M. H. Godby.

Captain Scott, of the British Antarctic Expedition, wrote acknowledging with thanks the offer of the Institute to place its library at the disposal of the officers of the "Terra Nova."

Animals Protection Act.—A copy of the Animals Protection Act as amended by the Legislative Council was received from Colonel Heaton Rhodes, M.P. General approval of the Act in its present form was expressed by the meeting, and a hearty vote of thanks was accorded to Colonel Rhodes for his energetic support of the proposals submitted to the Government by the Institute.

Papers.—1. "Classification of British Poetry: the Verse-unit," by Johannes C. Andersen.

This is the second paper dealing with the analysis of the units that form the metrical scheme of poetry. The former paper analysed the "foot" or "stress-unit"; the present paper analyses the "line" or "verse-unit." The lyric line only is dealt with; the heroic and blank verse must be the subject of separate analysis. It is shown that the lyric verse (the two lines as ordinarily printed) is normally a verse of eight stress-units, with varying number of syllables. The ordinary ballad verse of seven stress-units still observes the eighth in its end-pause; the Alexandrine and Nibelungen metres of six stress-units observe mid and end pauses. Upon these four main types is built the whole body of lyric poetry. The paper shows how certain constant variations may be taken as the forms for classifying poetry.

2. "Further Notes on New Zealand Bird-song," by Johannes C. Andersen.

This is a continuation of a previous paper, and it contains all the new notes or songs, or variations of the same, which have been recorded since the last paper was printed.

3. "The Rate of Oxidation of Acetaldehyde to Acetic Acid," by D. B. Macleod.

4. "The Conductivity of Aqueous Solutions of Carbon-dioxide prepared under Pressures of from One to Thirty Atmospheres," by C. M. Stubbs; communicated by Dr. W. P. Evans.

5. "The Depression of the Freezing-point by Carbon-dioxide," by F. D. Farrow.

6. "The Velocity of Evolution of Oxygen from Bleaching Powder Solutions in Presence of Small Quantities of Cobalt Nitrate," by N. M. Bell.

7. "The Chemical Composition of Meat-extract," by A. M. Wright.

8. "On certain Changes in the Composition of the Nitrogenous Constituents of Meat-extract," by A. M. Wright.

ANNUAL MEETING: *7th December, 1910.*

Present: Mr. R. M. Laing, President, in the chair, and forty others.

New Member.—Mr. J. D. Hall.

Annual Report.—The annual report as submitted by the Council was unanimously adopted.

ABSTRACT.

The condition of the Institute continues to be still most satisfactory both as regards the number of members and the active interest displayed in those special branches of scientific inquiry which constitute its aim and object. The special lines of research outlined in last year's report have been developed, and some have already given good results. These lines of inquiry are as follows. Observations on the Arthur's Pass Tunnel, a survey of the Canterbury lakes, and an examination of the Christchurch artesian system. This is quite apart from a considerable amount of original work which has been carried on by the individual members of the Institute.

Arthur's Pass Tunnel.—The temperature-observations have been regularly taken throughout the year at every 10 chains, and specimens collected at frequent intervals in order to have a permanent record of the rocks encountered. The lie of the beds, faults, and other features have been observed throughout the 86 chains that the bore has penetrated at the Otira end of the tunnel. Little work has been done at the Bealey end. The general results are somewhat inconclusive in that there has been no appreciable rise in temperature, a result which is no doubt due to the rapid percolation of water through the beds; and, since the Tunnel follows the general strike, little variation is to be met with in the character of the rocks encountered. The thanks of the Institute are due to Messrs. John McLean and Sons, the contractors, for the facilities afforded for the examination of the Tunnel, and to Mr. John Manson, of the Public Works Department, for the valuable services he has rendered in taking temperatures and collecting specimens when members of the Institute were unable to visit Otira.

Lakes Committee.—As mentioned in the report last year, it was originally intended to commence investigations on Lake Coleridge, and, as a preliminary step, a representative of the committee visited the lake. It was decided later to examine first a lake of smaller area, and Lake Sarah, on the West Coast Road, was therefore chosen. Early in the year three members spent a few days in the locality, and did some useful preliminary work, making collections and surveying the lake. On the completion of the present section of the Midland Railway, facilities for visiting the lake will be greatly increased, when it is hoped that the investigations may be continued.

Artesian Investigation.—Owing to pressure of other matters the Committee for the Investigation of the Artesian System of Christchurch and Neighbourhood has been unable to meet and work as a general committee: investigations have, however, been carried out by individual members, and a paper dealing with further experiments on the effect of artesian water on fish has already been presented at the Institute by Dr. Farr and Mr. D. B. Macleod, and a comprehensive paper dealing with the depths of the artesians in different districts and the strata through which they pass will be brought forward by Mr. R. Speight at the annual meeting.

Animals Protection Act.—This question has been fully considered by a sub-committee of the Council, and also by the Council itself working in conjunction with the local acclimatization society and the Otago Institute, and there is some satisfaction in noting that their combined efforts were successful in securing a modification of the present Act so as to give more adequate protection to our native fauna. A Government Bill recently introduced into Parliament contained a clause which declared all native birds to be protected, and imposed a substantial penalty for molesting them. The Hon. D. Buddo, Minister of Internal Affairs, has kindly informed the Council that this clause has been finally adopted, and it is hoped that it will check the destruction which went on formerly in spite of the regulations. The hearty thanks of the Institute are specially due to Mr. H. G. Ell, M.P., and to Colonel Heaton Rhodes, M.P., for their cordial and ready assistance in the matter.

Auckland Islands.—The Council notes with much pleasure the decision of the Government to make Adams Island, the large island to the south of Carnley Harbour, a sanctuary for the preservation of the unique native fauna and flora of our subantarctic islands. It is to be hoped that arrangements will also be made for

declaring as scenic reserves the two beautiful harbours on the east coast of the island—viz., Norman Inlet and Cascade Inlet: and also Ewing Island, at the north end of the group, with its remarkable forest of *Olearia Lyalli*, which, with the exception of a similar patch at the Snares, is the only one in existence. Norman Inlet is further remarkable as possessing the most southerly known tree-fern in the world.

"*Subantarctic Islands of New Zealand.*"—At the end of the year 1909 the report of the expedition to the southern islands of New Zealand, organized by this Institute, was issued to the public. The result has been specially gratifying to all concerned, the general appearance of the volumes reflects great credit on the printer, and it is confidently hoped that they will be welcomed by the scientific world as a substantial contribution to knowledge of the Antarctic, and especially of the part immediately to the south of New Zealand. The work has been well received throughout New Zealand and the Australian States, and the sales from this part of the world are very satisfactory. It is too early to speak of its reception in Europe and America, but judging from the few reviews that have been received, and from the cordial congratulations and appreciative references from such well-known men as Sir Joseph Hooker, Dr. W. S. Bruce, Professor L. Joubin, Dr. C. Skottsberg, Dr. L. Diels, an equally good reception may be expected from those parts of the world as well.

During the year the Institute communicated with the New Zealand Government urging the establishment of a high-power wireless telegraph-station at the Bluff, so that communication could be made with expeditions to the Antarctic equipped with a similar outfit. The Premier stated, in reply, that the station proposed by the New Zealand Government would be of sufficient power to communicate under favourable conditions with the Antarctic mainland. The Institute hopes that this may lead in the near future to the establishment of a permanent or semi-permanent meteorological station in the neighbourhood of Cape Adare, since such a station would prove of the very greatest value in making accurate weather-forecasts for Australia and New Zealand.

Library.—The amount spent on the library was far in excess of the proportion fixed by the constitution, and as many donations were also received, the additions are more than usually numerous.

As Port Lyttelton has been chosen as the point of departure for yet another British Antarctic Expedition, it is felt that the formation of a section dealing with works devoted to Antarctica was more than justified, and the Council was pleased to be able to place the library at the disposal of Captain Scott and his fellow-explorers of the "Terra Nova," to whom it has already proved of service.

The following are among the works added to the section during the year: "The Antarctic Regions": Fricker; 1904. "The Heart of the Antarctic": Shackleton: 1909. "The Birds of Terra del Fuego": Crawshay: 1907. Schwedische Süd-polar Exp. IV: Nordenskiold: 1901–3. National Antarctic Exp., 1901–3: Magnetic Observations. British Antarctic Exp., 1907–9: Rep. Scientific Observations—I, Biology: 1910. Exp. Antarctique Française, 1903–5 (in part); 1909 (*ed.* Charcot), presented by the French Government). "Mission Scientifique du Cap Horn": 1882–83. 1888–91. "Subantarctic Islands of New Zealand": 1909.

Meetings of the Institute.—Ten meetings of the Institute have been held during the year, at which the average attendance has been sixty-four. At these, twenty-seven papers embodying the results of original research have been read. These may be classified as follows: Botany, 4: zoology, 7: geology, 5; chemistry, 6: physics, 2: mathematics, 1: miscellaneous, 2. The number for the year is well up to the usual average, and it is pleasing to note that a fair proportion of these are by young members of the Institute. Besides these original papers the following addresses of a more general and popular character have been delivered: "The Nesting Habits of Fishes" (ex-presidential address), by Edgar R. Waite: "The Permanent Pastures of New Zealand," by A. H. Cockayne: "The Geology of the Cook and Society Islands," by Dr. P. Marshall: "Modern Views of the Constitution of Matter," by Dr. H. G. Denham.

Membership.—During the year thirty-one new members have been elected and twenty-six have resigned or been struck off, so that the number now stands at 173.

Balance-sheet.—The balance-sheet shows a credit on the Institute's ordinary account of £60 9s., and on the Tunnel Account of £142 10s. 11d. A sum of £101 15s. 8d. has been spent on the library, and £7 9s. has been collected and forwarded to the Hector Memorial Committee as a further contribution to that fund, in response to an appeal made by the committee to raise the total sum subscribed to £500, in order to secure the full Government subsidy.

Officers for 1911.—The following were elected officers of or the year 1911 : *President*—Mr. A. M. Wright : *Vice*-r. R. M. Laing, Dr. L. Cockayne ; *Hon. Secretary*—Mr. *Hon. Treasurer*—Dr. C. Chilton ; *Hon Librarian*—Mr. , *Council*—Dr. H. Brauer, Mr. J. Drummond, Dr. H. G. . F. W. Hilgendorf, Mr. E. G. Hogg, Mr. S. Page.

—1. "The Rediscovery of *Ranunculus crithmifolius*," by ig.

paper the author gives an account of the rediscovery of this species of *is* on the mountains at the head of the Cameron River, in Central Can-

'Some Hitherto-unrecorded Plant-habitats (VI)," by Dr. L. yne.

Note on the Dispersal of Marine *Crustacea* by Means of Ships," Chilton.

iper records the finding on the Lyttelton Dock of specimens of an Aus- aeromid, which had been brought over from Melbourne by adhering to the Antarctic Exploring Expedition ship "Terra Nova." Both male e specimens were found, and some of them were still alive when taken rack in a plank of the vessel, in which they had apparently harboured ie voyage. Other recorded instances of the dispersal of marine *Crustacea* s are quoted.

4. "Revision of the New Zealand *Stomatopoda*," by Dr. C. Chilton.

This paper is an account of the New Zealand *Squillidae*, supplementary to that published by the author in the Trans. N.Z. Inst., Vol. xxiii, p. 58. One additional species, *Lysiosquilla brazieri*, is added to the New Zealand fauna; it is an Australian species, and is probably identical with *L. latifrons* from Japan. Additional information with regard to other species is also given.

5. "Report on a Collection of *Crustacea* from the Kermadec Islands," by Dr. C. Chilton.

An account of the *Crustacea* collected at the Kermadec Islands in 1908 by Mr. W. R. B. Oliver and his companions. The collection is an extensive one, comprising over eighty species, all the main divisions of the *Crustacea* being represented. Nearly all the species prove to be identical with forms already known from Australia, New Caledonia, &c., the greater majority of them being Indo-Pacific species, and only a few belonging to the New Zealand fauna being represented.

6. "Glaciated Surfaces and Boulder-clay at the Bealey," by R. Speight (see below, p 98).

7. "Preliminary Account of the Geological Features of the Christchurch Artesian Area," by R. Speight.

In this paper an account is given of the water-bearing beds of the Christchurch artesian area, as deduced from the records kept for the past fifteen years by well-sinkers. The general sequence of the beds is represented by a series of vertical sections. Some account is also given of the source of the water, and special note is made of the occurrence of wells which are markedly affected by the tide. The paper is intended to be a preliminary to others dealing with various features of the area.

8. "On Centroidal Triangles," by E. G. Hogg.

9. "Report on the *Crustacea* collected by the 'Nora N Expedition," by Dr. C. Chilton.

An account of the *Crustacea* collected by Mr. Waite duri cruise of the "Nora Niven" in 1907. The collection is an intere particularly rich in the hermit-crabs, some of which have not been were taken by the "Novara" or "Challenger" expeditions. Al. referred to species already described, but in many cases additional given and the synonymy cleared up. [This paper will be published Results of the "Nora Niven" Trawling Expedition in the Records of t Museum.]

10. "Petrological Notes on a Collection of Rocks from toria Land," by R. H. Worth: communicated by T. V. Hodgso

This paper gives a petrological description of a number of specimens by Mr. T. V. Hodgson when a member of the British National Antarctic tion (1901 3). They include descriptions of material not required in the tion of the official report.

HAWKE'S BAY PHILOSOPHICAL INSTITUTE.

SIXTH MEETING: *5th November, 1910.*

Mr. J. Wilson Craig in the chair.

New Members.—Mr. W. J. W. Turvey and Mr. R. L. Paterson.

Paper.—"Torpedoes in Peace and in War," by W. J. W. Turvey.

The lecture gave an account, illustrated by lantern-slides, of the history, construction, machinery, and action of the torpedo.

Hocken Endowment Fund.—£5 was voted from the funds of the Institute in support of Hocken Endowment Fund.

ANNUAL GENERAL MEETING: *[illegible] January, 1911.*

Dr. Henley in the chair.

Report.—The annual report and balance-sheet were read and adopted, and ordered to be printed.

ANNUAL REPORT.

During the year seven meetings of the Institute were held, and the Council has met seven times.

Six papers have been read at the meetings.

Eleven new members were elected during the year, four members resigned, and one died, so that the membership is now seventy-four.

The society wishes to place on record its regret at the death of Mr. H. R. Holder, who was one of its oldest members.

The library still grows, over forty volumes having been added during the year. Two sets of valuable volumes have been presented to the library—"Hawkesworth's Voyages," presented by Mr. T. Hyde, and "The Institutes of the Emperor Akbar," presented anonymously. The thanks of the Institute are due to these donors.

The Institute has decided to encourage nature-study by offering prizes for collections of plants, shells, and insects. These prizes are offered through the Agricultural and Pastoral Society.

In order to fall in line with other Institutes and for convenience, the date of the annual meeting has been changed to December.

The Council, desiring to help in making the Hocken collection more available, decided to vote £5 for that purpose.

The Treasurer's statement shows that the Institute is in a sound position, there being a credit balance of £23.

Election of Officers for 1911.—*President*—H. Hill, B.A., F.G.S.; *Vice-President*—T. C. Moore, M.D.; *Council*—G. Clark, W. Dinwiddie, J. Hislop, J. P. Leahy, M.B., D.Ph., G. K. Sinclair, J. Snodgrass; *Hon. Secretary*—J. Niven, M.A., M.Sc.; *Hon. Treasurer*—J. W. Craig; *Hon. Auditor*—J. S. Large; *Hon. Lanternist*—E. G. Loten.

Valedictory.—On behalf of the Institute, Mr. Craig wished the President (Dr. Henley) a safe journey to England, and a pleasant holiday there.

MANAWATU PHILOSOPHICAL SOCIETY.

ANNUAL MEETING: *7th December, 1910.*

The President, Mr. W. F. Durward, in the chair.

The annual meeting (adjourned from the 24th November) was held on the above date. The annual report and balance-sheet were adopted.

ANNUAL REPORT.

Since the last annual meeting only five general meetings have been held, as those from May to August lapsed, several gentlemen who had been expected to read papers having been prevented from various reasons from doing so.

During the year one of our members has been removed by death. five by leaving the district, three by resignation, and three have been struck off the list for non-payment of their subscriptions. During the same time five new members have been elected. and our present roll is sixty-five.

In consequence of the lamented death of Mr. Keeling, the Council subsequently appointed Mr. J. Mitchell auditor in his place.

The following papers have been read before the society: Mr. W. W. Smith, F.E.S.: "The New Zealand Saddleback." Mr. D. Sinclair, C.E.: "Education among the Early Maoris." Dr. Findlay, LL.D., K.C.: "Legal Liberty." Mr. E. D. Hoben: "The Moving Picture." Mr. R. McNab: "Recent Researches into the History of Te Rauparaha's Raid on Akaroa in 1830, and the French Race for the same Place in 1840."

An admirably mounted collection of ferns was exhibited at the Agricultural and Pastoral Winter Show by Mr. T. Lancaster, which, though not entirely fulfilling the conditions attached to the prizes offered by the society, was so highly commended by the Judge, Mr. T. W. Kirk, F.L.S., that the Council awarded to it a prize of £2 2s.. and on the judge's recommendation further altered the conditions so that, in future, collections sent in in competition for the prizes may be confined to any one or more orders in either botany or entomology. a limitation which the Council hope may encourage more competitors to enter.

Individual additions both to the museum and the library continue to come in steadily. many of them of considerable interest, there having been over 150 during the year; but the Council has been compelled to decline representative collections which have been offered by Government Departments and by individuals, on account of the total want of space available for their display. In view of the recent rejection of the loan for a new library and museum, some definite plan for obtaining increased accommodation is urgently required. An application has been made on behalf of the society for the use of the old fire-brigade station. or a portion of it. as a museum; and. failing that, it seems a matter for serious consideration whether the society should not try to raise funds for a building of its own. A site could be probably obtained either from the Corporation or the Government. and Mr. Sinclair has kindly prepared an estimate showing that a brick building providing accommodation that would be adequate for many years might be put up for from £650 to £700.

A reference to the statement of receipts and expenditure will show that if all outstanding subscriptions were paid up the society's overdraft would be reduced to £1.

A report by Captain Hewitt on the work of the Observatory is attached:—

Report on Observatory Work during 1909–10, *by Captain Hewitt.*

During the past year we have had only forty-nine visitors, though during the comet's visit, with the kind assistance of Messrs. Eliott and Glendinning, the Observatory was open three evenings a week. We have had only one visit from the public schools, when Mr. Vernon brought some pupils from the High School.

Observations of Halley's comet were interesting, especially before its passage of the sun, when its tail was increasing. At 5 a.m. on 18th May the tail, well defined, exceeded 75° of arc, and at 3 a.m. on the 19th the tail, very diffused, covered the N.E. quarter of the heavens nearly to the zenith; at 5 a.m., no defined limits to the tail—apparently the earth was in the tail.

The dates of the comet's first appearance may be of interest. On 14th September, 1909, it was seen at Yerke's Observatory, when the observed position differed only 3 in R.A. and 4′ in decl. from the position calculated for the Pulkowa Observatory. On 18th October, 1909, it was found on a photograph-plate at Meeanee. Here it was not seen till 18th April, 1910, in the constellation Pisces, where, though approaching the earth rapidly, it appeared to remain till 4th May, when change of position was easily perceived. On 21st April the tail extended about 45′; on 13th May I estimated it at 20°, reaching about 5° above α Pegasi. The observed position of the nucleus was then R.A. 0° 39′ 40″, decl. 11° 48′ N. At 5 a.m. on 18th May the tail stretched from the horizon at E.N.E. to a point about 7° above Altair—say, 75° of arc. At 6 a.m. the nucleus had not risen, and daylight effaced the light of the comet. On 21st May I observed the comet in the evening, in position R.A. 5h. 51′ 45″, and decl. 18° 11′ N. This is near the calculated position between the 18th and 19th, but 3° further north. This looks as if the comet had been retarded in its progress, though I have not heard of any one who observed the position that evening. On the following evening, 22nd May, Mr. Ward's observation at Wanganui agrees closely with mine; but if the comet was checked, subsequent observations on fourteen evenings up to 24th June show that it was gradually making up for lost time.

Observations of sun-spots have been interesting, confirming me in the idea, put before you some three years ago, that we must consider solar forces as converging on our earth and planets of our system, rather than that these bodies catch the chance rays which may hit them from a body which radiates force into space, heedless whether there is matter for those forces to act on. Unfortunately, times of magnetic disturbance are generally accompanied by bad weather, when the sun is obscured by clouds, so simultaneous observations of spots and magnetic oscillations are rare; but on two occasions —25th September and 29th November, 1909—I noted considerable movement in spots on the southern hemisphere of the sun, and the Surveyor-General's report, when published, showed that on those days there had been magnetic disturbance in the observatory at Christchurch. Commenting on these coincidences to the Surveyor-General, I was able to draw his attention to solar disturbances which I suspected had caused magnetic disturbances between 29th September and 6th October, 1910. He referred my letter to Mr. Skey, at Christchurch, who replied that the magnetograms showed considerable disturbance from 29th September to 7th October. This encourages us to ask for more observers of these phenomena, so that we may get more knowledge of that mysterious force magnetism.

We have received from Messrs. Home and Thounthwaite, at a cost of 16s., an eyepiece to replace the 70-power one that was injured.

I have to thank Messrs. Eliott and Glendinning for kind assistance when I have been unable to attend.

Papers.—1. "Local Vegetable Parasites," by D. Sinclair, C.E.

This paper dealt with some of the New Zealand mistletoes, contrasting them with the European species; also with *Dactylanthus Taylori*, which was stated to grow on the roots of the white miri (*Pittosporum*), appearing about 2 in. above ground like a fir-cone on end, and with the flower in the centre tinged with pink. The plant is rare, and its means of propagation unknown. Reference was also made to various New Zealand epiphytes.

In the course of his paper the author suggested the formation of a field naturalist club in connection with the society.

2. "Assumption of the Sword of the Sutter of the Maldive Islands," by W. F. Durward.

This was an account given by the brother of the author, an officer on H.M.S. "Proserpine," of the curious ceremonies on the "assumption of the sword" by the sutter of the Maldive Islands, the local equivalent to coronation. Special attention was called to the employment of seven as a mystical number symbolic of royalty, the whole procession being arranged in sevens, and the proceedings being repeated at seven different stations.

3. "The Evidences of the Condition of the Interior of the Earth," by M. A Eliott.

ABSTRACT.

1. Gravitation proves that the total mass of the earth is $5\frac{1}{2}$ times heavier than water, the weight increasing towards the interior, the surface being from $2\frac{1}{2}$ to $3\frac{1}{2}$, and the interior more than 8 times heavier than water.

2. The shape of the earth shows that the density of the mass increases towards the centre, and in such proportion that the rocky shell must be from 800 to 1,000 miles thick.

3. (*a.*) The tides prove that the globe as a whole must be as rigid as steel, though at the same time flexible, the core being 4 times as rigid as steel. (*b.*) Polar oscillations show that the interior is of a plastic nature.

4. Earthquakes prove that at a depth of 950 miles—*i.e.*, the point of passage from the rock mantle to the metal core—a sudden change occurs in the condition of the strata.

5. The temperature increases rapidly towards the centre, probably to thousands of degrees, liquefaction, however, being prevented by the enormous pressure.

6. The moon, formed from the same materials as the outer layers of the earth, is known from astronomical observations to have a density of 3·4, coinciding exactly with the average density of the rocky mantle.

Thus the final conclusion is that the earth consists of a metal core, composed principally of iron, with some alloy of heavier metal, as nickel, surrounded by a rocky mantle about 950 miles thick.

Election of Officers for 1911.—President—Captain Hewitt, R.N., *Vice-Presidents* — Messrs. R. McNab and R. Gardner; *Secretary and Treasurer*—Mr. K. Wilson; *Auditor*—Mr. J. Mitchell; *Council*—Messrs. Barnicote, Bendall, Durward, Eliott, Sinclair, and Vernon.

OTAGO INSTITUTE.

SEVENTH MEETING: *1st November, 1910.*

Professor Waters, President, in the chair.

New Members.—Dr. Champtaloup and Mr. D. Tannock.

Papers.—1. "The Kinetic Energy of River-currents; or The Utilization of River-currents for Power Purposes," by F. W. Payne.

The author showed interesting photographs of a current-wheel which he had constructed and erected at Alexandra, and gave an account of its power and working-capacity, and the quantity of water it could lift and discharge, and showed clearly that there was an almost unlimited supply of power entirely untouched in the midst of a great district with enormous possibilities in the way of fruit-production under a comparatively economical system of irrigation. In the course of the discussion that followed Mr. Payne stated that the wheels could be multiplied indefinitely on a river such as the Clutha, and that the cost per head by current-wheel was about £500, as against £1,400 per head for water brought in by the usual pipe-lines.

2. "Report on the Echinoderms collected at the Kermadec Islands," by Professor Benham, F.R.S

3. "A New Species of *Syrphidae*," by D. Miller.

4. "Anatomy of *Siphonaria obliquata*," by A. J. Cottrell.

5. "Description of Some New Species of New Zealand *Lepidoptera*," by G. Howes.

6. "The Younger Rock Series of New Zealand," by Professor P. Marshall, D.Sc.

Address.—Mr. A. Bathgate gave an interesting account of a trip to the Waitomo Caves and to the north-west portion of the Nelson Province.

EIGHTH MEETING: *6th December, 1910.*

Professor Waters, President, in the chair.

New Members.—Messrs. J. Laing and G. E. Thompson, M.A.

Exhibit.—Professor Benham exhibited a very fine greenstone axe, measuring 11 in. by 6 in., discovered at a depth of about 6 ft. at the corner of Leith and Hanover Streets, Dunedin. The axe had been dug up by the workmen of the Drainage Board, which body had commendably donated the implement to the Museum.

Governor.—Mr. G. M. Thomson being unable to attend the next annual meeting of the New Zealand Institute, Dr. P. Marshall was elected a substitute Governor in his place.

ANNUAL MEETING: *6th December, 1910.*

Professor Waters, President, in the chair

The annual report and balance-sheet were adopted.

ANNUAL REPORT.

Work of the Council.—The Council has met twelve times for the transaction of the business of the Institute, of which the following is a summary :—

Your Council co-operated with the Philosophical Institute of Canterbury in sending an emphatic protest to the Prime Minister against the destruction of seals on the outlying southern islands. The Prime Minister promised that the matter would have his attention in due course.

Your Council this year decided to offer three prizes of half a guinea each to the primary schools of Otago for the best naturalists' calendar, the best collection of insects, and the best collection of plants. The awards for this year have not yet been made.

A contribution of £25 was made to the Hocken Memorial Fund, and your Council endeavoured to induce the affiliated societies to assist in the upkeep of this national asset. We regret to say that we have received no satisfactory response from any of the affiliated societies.

Having considered the amendments in the Animals Protection Act submitted by the Philosophical Institute of Canterbury, and having found them satisfactory, your Council sent word of our willingness to act with it in urging the Government to accept the amendments.

During the year your Council communicated with the Southland Land Board and the Minister of Lands, protesting against the re-lease of the Auckland Islands to a whaling enterprise, on the grounds that such enterprise is very destructive to the flora and fauna of the islands. A satisfactory assurance was received from the Minister that Adams Island would be set apart as a reserve, and that every endeavour would be made to preserve the flora and fauna on the most important areas of the islands.

Viewing with regret the great destruction of penguins and sea-elephants on the Macquaries, your Council sent representations to the local members of Parliament, the Prime Minister, and others, protesting against this, and asking for protection of the animals mentioned. Unfortunately, these islands are under the jurisdiction of Tasmania, and the New Zealand Government declined to interfere. Correspondence also took place between your Council and the Tasmanian Government and several scientific societies in Tasmania and Australia. Unfortunately, your Council has no means of proving the amount of destruction or the actual decrease of these interesting animals beyond hearsay, and the Government of Tasmania seems disposed to grant a re-lease to the owner of the oil industry on the islands, Mr. Hatch, who flatly contradicts our statements as to the damage done.

Recognizing the need for expert advice in dealing with the subject of afforestation in New Zealand, your Council sent a strong letter to the Prime Minister urging such an appointment. The Prime Minister, however, assured us that the Government have at their disposal at the present time several highly trained experts, and do not consider any further appointment necessary.

Personnel of the Council.—Dr. Fitchett was appointed a member of the Council, *vice* Dr. Malcolm (resigned); Mr. Alex. Bathgate was appointed Vice-President, *vice* Dr. Hocken (deceased); and Mr. E. J. Parr was appointed to a vacancy on the Council.

Ordinary Meetings.—Papers and addresses have been given by the President (Professor Waters), Professor Marshall, Professor Park, Dr. Fulton, and Mr. F. W. Payne, and a number of technical and scientific papers have been read and placed upon the table for publication in the Transactions. Many interesting exhibits have been shown by Professor Waters, Dr. Benham, Mr. George Howes, Professor Park, Professor Marshall, and others.

In pursuance of its custom, your Council invited Dr. Leonard Cockayne, F.L.S., of Christchurch, a specialist in ecological botany, to deliver an address before our members. The lecture, which was beautifully illustrated with lantern-slides, was well attended and much appreciated. The subject was, "The Scientific Importance of our Scenic Reserves and National Parks," and the speaker gave a graphic account of the various types of floral growth upon our islands and forest areas.

Membership.—During the current session thirteen new members have joined the Institute, two have resigned, and one—our lamented Vice-President, Dr. Hocken—has been taken from us by death. Full references to his eminent services and

the great loss sustained by the New Zealand Institute will be found in the minutes of the ordinary meetings and inscribed in a permanent memorial in the volume of Transactions and Proceedings.

The Hocken Memorial, or Museum Wing, is a permanent landmark which will keep fresh in our memory one of our most active workers, and a member of the Otago Institute for a period approaching half a century.

Our membership is now 134, an increase of ten over last year's roll.

Library.—The additions to the library during the last year have been greater than usual, partly owing to the generous donation of books by the late Dr. Hocken, and partly to the number of purchases of zoological works made in accordance with an agreement with the other libraries that this Institute should specialize in works on general zoology and geology. The existing shelves are nearly full. A few years back additional accommodation was effected by the erection of shelves in the room of the Curator of the Museum, and this year the librarian was compelled to obtain permission from the Council to have some small ones built over the door. But the time is close at hand when the accommodation for periodicals will be fully occupied, and it will be necessary to consider seriously how further accommodation can be provided. A judicious culling-out of old out-of-date works ought to be undertaken this summer.

The Council authorized the sale to Messrs. Bowes and Bowes, of Cambridge, of our set of the *Philosophical Magazine*, for which those booksellers were advertising. As this periodical is taken by the University, and as it had not been consulted by our members for some years, the opportunity of disposing of the set for a fair price was taken.

The following additions have been made during the year. Donations (in addition to the reports presented by the Government): Dr. Hocken—"Geographical Journal," for the last nine years; "Journal of the Anthropological Institute," for ten years; "Man," six volumes. Mr. G. M. Thomson—Twenty-seven pamphlets on zoological subjects; Forster's "Character: Generum Plantarum" (folio). 1776. Dr. H. Lindo Ferguson—Twenty-two volumes of the Transactions of the New Zealand Institute (volumes xvii-xxxix, minus xxxiii and xxiv). Dr. P. Marshall—Nicholson's "Palaeozoic Corals—the Monticuliporidae" Numerous additions by purchase were also made.

Thanks.—The Council and members desire to thank those ladies who have been kind enough to provide and superintend the distribution of refreshments at our meetings. Our thanks are due to the Otago Employers' Association for kindly allowing the Council to hold its meetings in its board-room.

Balance-sheet.—The balance-sheet, presented by the Treasurer (Mr. J. C. Thomson), showed a credit balance of £59 11s. 8d. The finances of the Institute are in a satisfactory condition.

Officers for 1911.—President—Mr. Alex. Bathgate; *Vice-Presidents*—Professor W. B. Benham, D.Sc., F.R.S., Professor D. B. Waters, A.O.S.M.; *Council*—Dr. R. V. Fulton, Dr. S. C. Allen, Mr. J. C. Thomson, Professor P. Marshall, M.A., D.Sc., F.G.S., Professor J. Malcolm, M.D., Mr. F. H. Statham, A.O.S.M., Mr. G. M. Thomson, M.P., F.L.S.; *Hon Treasurer*—W. Fels; *Hon. Secretary*—E. J. Parr, M.A., B.Sc.; *Hon. Librarian*—Dr. Benham; *Hon. Auditor*—Mr. D. Brent, M.A.

PAPERS.

1. Glaciated Surfaces and Boulder-clay near Bealey. By R. Speight, M.Sc., F.G.S. (Read before the Philosophical Institute of Canterbury, 7th December, 1910.)

Glaciated surfaces where actual striae still remain clearly visible have not been often recorded as occurring in this country, nevertheless a careful inspection of likely places shows that they are by no means infrequent. During a visit to the Bealey I had opportunity to examine minutely several places where ice was likely to leave its traces, and specially the large *roche moutonnée* near which the Bealey Hotel is situated. This is in all probability an outlying fragment of a former spur which has been almost entirely removed by the erosion of the great valley glacier which occupied the Waimakariri Valley in former times, and its surface exhibits in many places the characteristic striae and flutings due to glacier erosion. These have remained hidden for years, but recent heavy rains have removed the covering of soil and clay and exposed the surface of the solid rock to view for over 3 chains along the roadside. The flutings and striae are not parallel to the axis of the valley, but make a small angle with it. The general surface of the mound shows the dimples usually associated with glacier-eroded surfaces. Similar dimples are to be observed on Goldney's Saddle, about seven miles below the Bealey near the junction of the Cass with the Waimakariri. In order that these forms may be well preserved, they must be protected from the disintegrating action of frost, which quickly breaks up any exposed surface in this region. The rapidity of this mode of disintegration is well shown on the surfaces of rocks on Goldney's Saddle, where they have been deprived of their blanket of clay, loess, or peat. The completeness of this protective covering accounts for the surface markings being so well preserved at the Bealey. On close examination this appears to be composed of an upper layer of loose material, yellowish-brown in colour, closely resembling loess, but not a true loess. The actual thickness is doubtful, and no doubt highly variable, but where exposed on the roadside it is from 4 ft. to 5 ft. thick. This portion owes its origin partly to material contained in the ice and left behind when it melted, partly to material weathered at higher levels and carried down by the action of water, snow, &c., and partly to the fine rock-flour which has been swept by strong winds from the dry river-beds left exposed as the ice retreated. The most interesting part, however, is the bottom layer of about 18 in. thick. This consists of a stiff clay containing subangular stones which are frequently striated—that is, it is a true boulder-clay, the first recorded from New Zealand which exhibits all its special characters. Such clays have been reported, but without the presence of scratched stones. In this case they are common, and a dozen good examples were collected in the course of two forenoons. It must be stated, however, in order to prevent possible misunderstanding, that a portion of the upper surface of the *roche moutonnée* had been ploughed, and scratched stones were turned up in this part of it. It might be urged that the scratches on the stones were marks produced by the ploughshare were not equally good specimens found in the clay on that part of the hill which had not been broken up. No doubt this clay collected in some of the hollows formed in the rock-surface by the erosive action of the glacier.

Striated surfaces are also to be seen in the locality on the side of the road just past the hotel, and a very well-marked occurrence was pointed out to me by Mr. Patterson, the Public Works Engineer, about six miles below the Bealey, on the Waimakariri cutting, near the site of the projected railway-bridge over the river. Curiosity-hunters are rapidly destroying this surface in the desire to obtain specimens.

Both these occurrences owe their preservation to the protection afforded by the surface layer of loose material, and they have only been recently exposed.

2. Notes on the Discovery of Dactylanthus Taylori. By James Grant, B.A.; communicated by Mr. T. W. Downes. (Read before the Wellington Philosophical Society, 7th September, 1910.)

In Vol. xli of the "Transactions of the New Zealand Institute" Mr. H. Hill, in describing the *Dactylanthus Taylori*, quotes a letter he received from Mr. D. H. Williamson, in which that writer claims that his father, the late Francis Williamson,

was the discoverer of the plant, but that instead of sending it to England as he originally intended he gave it to the Rev. Richard Taylor, who was then on the point of paying a visit to the Old Country. The concluding sentence of the letter indicates that Mr. Williamson has a grievance against Mr. Taylor because Dr. Hooker (now Sir Joseph) associated the name of the veteran missionary with the plant.

The Rev. R. Taylor came to New Zealand in March, 1839, and paid his first visit to England in 1855. Hence the late Mr. Williamson must have found his specimen early in that year. Possibly Mr. D. H. Williamson was led to make the claim on behalf of his late father on reading an article in Vol. xxviii of the Transactions where the late Mr. T. Kirk mentions 1857 as the probable date of Taylor's discovery. But, as Mr. Hill points out, there is a sketch of the *Dactylanthus* in Taylor's "Te Ika a Maui," which was published in 1855.

In the second edition of "Te Ika a Maui" (page 697) Taylor says, "I first found it (*Dactylanthus*) on a mountain-range near Hikurangi, returning from Taupo, and noticed it growing among the roots of a tree near the path. . . . Mr. Williamson afterwards brought me another specimen which he had found in clearing some ground. The whole plant and flowers were entirely covered with vegetable mould; the stem between the bracts was of a rusty brown. There were twenty-five flowers open all at once; another excrescence had eighteen. He states the odour of one plant was something like that of a ripe melon, whilst the other had a disagreeable earthy smell."

Dr. Hooker, who described and named the plant, says, "For a specimen of this singular plant I am indebted to my friend the Rev. R. Taylor, of New Zealand, who brought a fragment of it to England in 1856, and, on my pointing out its probable interest, promised to procure more on his return to New Zealand. This he did, and early in the present year (1859) I had the pleasure of receiving from him a dried specimen of a female plant, a perfect male inflorescence in a letter, and a pen-and-ink sketch of the peduncle and flowers, with notes on the same."

The most important evidence was discovered by Mrs. Harper, the wife of Mr. H. S. G. Harper, in whose possession the Rev. R. Taylor's unpublished journals are. The whole entry for the day is copied out exactly as it stands, except that the writer of these notes has supplied the punctuation-marks.

"March 18, 1845.—It was a rainy night, and very cold, wet, and cheerless. In walking through the dense, humid forest I was soon as wet as if I had been in the water. We had constantly been ascending and descending. We crossed the Mangawera [Mangawhero] after dinner. The stream here makes a remarkable noise, which I fancy is occasioned by its flowing through some cavern in the rock. The Natives say it is a large tuna. I found the *Parei* myself to-day. It is certainly one of the most remarkable vegetable productions I have seen, and appears to be the union of fungus with the plant. I passed several, taking them for toadstools, but one more remarkable than the rest caused me to stop and gather it. I then found that it was a plant in full flower, although very much resembling a fungus. It has no leaves, and has a calyx containing a kind of pollen with rather a disagreeable smell. The Natives say it is more prolific than the potato, but will only grow in the forest. We passed through several small *munias* to-day and had some very wearisome and precipitous ascents. We are encamped for the night where the road for Pukehika branches off from that to Ikurangi [Hikurangi]."

This quotation, the compiler ventures to think, establishes the fact that the Rev. R. Taylor discovered the *Dactylanthus* in 1845. It is not improbable that the specimen received by Hooker in 1856 is the one Mr. Williamson refers to in his letter. But as Taylor had seen the plant more than ten years previously, he could hardly be expected to represent it to Hooker as the discovery of another man. Besides, he is quite frank in mentioning the specimen he received from Williamson. So I think the hint in the conclusion of Mr. Williamson's letter that Taylor was guilty of something akin to sharp practice has nothing to support it.

These notes have been compiled to vindicate the character of the Rev. R. Taylor, a man who worked strenuously not only for the good of the Natives, but also for the public generally. Like many more overworked men, he found time to study the natural history of the district over which he made so many journeys. He wrote two books, the second edition of one of these being practically a new work, numerous articles of a scientific nature, besides many volumes of unpublished matter.

Unfortunately, no biography of Taylor has yet been written. Until some one accomplishes that work the man will remain unknown. Suffice it to say here that, even if the evidence in his diary had not been forthcoming, the man was so upright in character that he would never have been guilty of attempting to appropriate another man's discovery.

3. Geoplana aucklandica and Geoplana marrineri: a Correction in Nomenclature. By Arthur Dendy, D.Sc., F.R.S.

In my article "On Land Planarians from Auckland and Enderby Islands," in the "Subantarctic Islands of New Zealand" (Wellington, N.Z., 1909), I have described a new species from Auckland Island under the name *Geoplana aucklandica*, having overlooked the fact that I had myself eight years previously given this name to a totally different species from a widely separated locality—viz., Auckland, in the North Island of New Zealand.

I now desire to rectify this error by proposing a new specific name for the subantarctic form from Auckland Island, and I suggest that it be called *Geoplana marrineri*, in acknowledgment of the services rendered to the study of zoology in New Zealand by my late friend and assistant, George R. Marriner.

4. Notes on the Vegetable Caterpillar. By G. Howes, F.E.S.

During a recent visit to Riverton I raided a patch of the well-known vegetable caterpillar. This patch I have known of for some years, and have on several occasions drawn on it for specimens for friends. The patch of bush where they occur is but small, and the more open spaces have been depleted, but amongst the stems and roots of shrubs and creepers a fair number of the spore-bearing spikes appear.

Digging had to be carefully carried out, as carelessness or rough handling caused breakage and spoilt the specimen; indeed, it was impossible to dig up any particular specimen without running the risk of breaking some other near by. The special point I wish to place on record is that fragments from specimens accidentally broken and again buried during some previous search had sent out healthy spore-bearing spikes. Several of these fragments were less than 1 in. in length, while one of about 2 in. (being the tail half) had grown two fair-sized spikes

Along with the fungi I took an apparently healthy larva of *Porina dinodes* and, so far as I could see, all the vegetable caterpillars there were those of this moth. The largest specimen I took was 5 in., but I have never seen a living *dinodes* larva of this length, and suppose that the fungus growth distends the skin of its host.

APPENDIX.

NEW ZEALAND INSTITUTE ACTS.

NEW ZEALAND INSTITUTE ACT, 1903.

The following Act reconstituting the Institute was passed by Parliament.—

1903, No. 48.

An Act to reconstitute the New Zealand Institute.

[*18th November, 1903.*

Whereas it is desirable to reconstitute the New Zealand Institute with a view to connecting it more closely with the affiliated institutions:

Be it therefore enacted by the General Assembly of New Zealand in Parliament assembled, and by the authority of the same, as follows:—

1. The Short Title of this Act is the New Zealand Institute Act, 1903.

2. The New Zealand Institute Act, 1867, is hereby repealed.

3. (1.) The body hitherto known as the New Zealand Institute (hereinafter referred to as "the Institute") shall consist of the Auckland Institute, the Wellington Philosophical Society, the Philosophical Institute of Canterbury, the Otago Institute, the Hawke's Bay Philosophical Institute, the Nelson Institute, the Westland Institute, the Southland Institute, and such others as may hereafter be incorporated in accordance with regulations to be made by the Board of Governors as hereinafter mentioned.

(2.) Members of the above-named incorporated societies shall be *ipso facto* members of the Institute.

4. The control and management of the Institute shall be in the hands of a Board of Governors, constituted as follows:—

The Governor;

The Colonial Secretary;

Four members to be appointed by the Governor in Council during the month of December, one thousand nine hundred and three, and two members to be similarly appointed during the month of December in every succeeding year;

Two members to be appointed by each of the incorporated societies at Auckland, Wellington, Christchurch, and Dunedin during the month of December in each alternate year;

One member to be appointed by each of the other incorporated societies during the month of December in each alternate year.

5. (1.) Of the members appointed by the Governor in Council two shall retire annually on the appointment of their successors; the first two members to retire shall be decided by lot, and thereafter the two members longest in office without reappointment shall retire.

(2.) Subject to the provisions of the last preceding subsection, the appointed members of the Board shall hold office until the appointment of their successors.

6. The Board of Governors as above constituted shall be a body corporate, by the name of the "New Zealand Institute," and by that name they shall have perpetual succession and a common seal, and may sue and be sued, and shall have power and authority to take, purchase, and hold lands for the purposes hereinafter mentioned.

7. (1.) The Board of Governors shall have power to appoint a fit person, to be known as the "President," to superintend and carry out all necessary work in connection with the affairs of the Institute, and to provide him with such further assistance as may be required.

(2.) It shall also appoint the President or some other fit person to be editor of the Transactions of the Institute, and may appoint a committee to assist him in the work of editing the same.

(3.) It shall have power to make regulations under which societies may become incorporated to the Institute, and to declare that any incorporated society shall cease to be incorporated if such regulations are not complied with, and such regulations on being published in the *Gazette* shall have the force of law.

(4.) The Board may receive any grants, bequests, or gifts of books or specimens of any kind whatsoever for the use of the Institute, and dispose of them as it thinks fit.

(5.) The Board shall have control of the property hereinafter vested in it, and of any additions hereafter made thereto, and shall make regulations for the management of the same, for the encouragement of research by the members of the Institute, and in all matters, specified or unspecified, shall have power to act for and on behalf of the Institute.

8. Any casual vacancy on the Board of Governors, howsoever caused, shall be filled within three months by the society or authority that appointed the member whose place has become vacant, and if not filled within that time the vacancy shall be filled by the Board of Governors.

9. (1.) The first annual meeting of the Board of Governors hereinbefore constituted shall be held at Wellington on some day in the month of January, one thousand nine hundred and four, to be fixed by the Governor, and annual meetings of the Board shall be regularly held thereafter during the month of January in each year, the date and place of such annual meeting to be fixed at the previous annual meeting.

(2.) The Board of Governors may meet during the year at such other times and places as it deems necessary.

(3.) At each annual meeting the President shall present to the meeting a report of the work of the Institute for the year preceding, and a balance-sheet, duly audited, of all sums received and paid on behalf of the Institute.

10. The Board of Governors may from time to time, as it sees fit, make arrangements for the holding of general meetings of members of the Institute, at times and places to be arranged, for the reading of scientific papers, the delivery of lectures, and for the general promotion of science in the colony by any means that may appear desirable.

11. The Colonial Treasurer shall, without further appropriation than this Act, pay to the Board of Governors the annual sum of five hundred pounds, to be applied in or towards payment of the general current expenses of the Institute.

12. (1.) On the appointment of the first Board of Governors under this Act the Board of Governors constituted under the Act hereby repealed shall cease to exist, and the property then vested in, or belonging to, or under the control of that Board shall be vested in His Majesty for the use and benefit of the public.

(2.) On the recommendation of the President of the Institute the Governor may at any time hereinafter, by Order in Council, declare that any part of such property specified in the Order shall be vested in the Board constituted under this Act

13. All regulations, together with a copy of the Transactions of the Institute, shall be laid upon the table of both Houses of Parliament within twenty days after the meeting thereof.

NEW ZEALAND INSTITUTE ACT, 1908.

1908, No. 130.

AN ACT to consolidate certain Enactments of the General Assembly relating to the New Zealand Institute.

BE IT ENACTED by the General Assembly of New Zealand in Parliament assembled, and by the authority of the same, as follows:—

1. (1.) The Short Title of this Act is the New Zealand Institute Act, 1908.

(2.) This Act is a consolidation of the enactments mentioned in the Schedule hereto, and with respect to those enactments the following provisions shall apply:—

(a.) The Institute and Board respectively constituted under those enactments, and subsisting on the coming into operation of this Act, shall be deemed to be the same Institute and Board respectively constituted under this Act without any change of constitution or corporate entity or otherwise; and the members thereof in office on the coming into operation of this Act shall continue in office until their successors under this Act come into office.

(b.) All Orders in Council, regulations, appointments, societies incorporated with the Institute, and generally all acts of authority which originated under the said enactments or any enactment thereby repealed, and are subsisting or in force on the coming into operation of this Act, shall enure for the purposes of this Act as fully and effectually as if they had originated under the corresponding provisions of this Act, and accordingly shall, where necessary, be deemed to have so originated.

(c.) All property vested in the Board constituted as aforesaid shall be deemed to be vested in the Board established and recognized by this Act.

(d.) All matters and proceedings commenced under the said enactments, and pending or in progress on the coming into operation of this Act, may be continued, completed, and enforced under this Act.

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* See *New Zealand Gazette*, 1st September, 1904.

2. (1.) The body now known as the New Zealand Institute (hereinafter referred to as "the Institute") shall consist of the Auckland Institute, the Wellington Philosophical Society, the Philosophical Institute of Canterbury, the Otago Institute, the Hawke's Bay Philosophical Institute, the Nelson Institute, the Westland Institute, the Southland Institute, and such others as heretofore have been or may hereafter be incorporated therewith in accordance with regulations heretofore made or hereafter to be made by the Board of Governors.

(2.) Members of the above-named incorporated societies shall be *ipso facto* members of the Institute.

3. The control and management of the Institute shall be vested in a Board of Governors (hereinafter referred to as "the Board"), constituted as follows:—

The Governor:

The Minister of Internal Affairs:

Four members to be appointed by the Governor in Council, of whom two shall be appointed during the month of December in every year:

Two members to be appointed by each of the incorporated societies at Auckland, Wellington, Christchurch, and Dunedin during the month of December in each alternate year; and the next year in which such an appointment shall be made is the year one thousand nine hundred and nine:

One member to be appointed by each of the other incorporated societies during the month of December in each alternate year; and the next year in which such an appointment shall be made is the year one thousand nine hundred and nine.

4. (1.) Of the members appointed by the Governor in Council, the two members longest in office without reappointment shall retire annually on the appointment of their successors.

(2.) Subject to the last preceding subsection, the appointed members of the Board shall hold office until the appointment of their successors.

5. The Board shall be a body corporate by the name of the "New Zealand Institute," and by that name shall have perpetual succession and a common seal, and may sue and be sued, and shall have power and authority to take, purchase, and hold lands for the purposes hereinafter mentioned.

6. (1.) The Board shall have power to appoint a fit person, to be known as the "President," to superintend and carry out all necessary work in connection with the affairs of the Institute, and to provide him with such further assistance as may be required.

(2.) The Board shall also appoint the President or some other fit person to be editor of the Transactions of the Institute, and may appoint a committee to assist him in the work of editing the same.

(3.) The Board shall have power from time to time to make regulations under which societies may become incorporated with the Institute, and to declare that any incorporated society shall cease to be incorporated if such regulations are not complied with; and such regulations on being published in the *Gazette* shall have the force of law.

(4.) The Board may receive any grants, bequests, or gifts of books or specimens of any kind whatsoever for the use of the Institute, and dispose of them as it thinks fit.

(5.) The Board shall have control of the property from time to time vested in it or acquired by it; and shall make regulations for the

management of the same, and for the encouragement of research by the members of the Institute; and in all matters, specified or unspecified, shall have power to act for and on behalf of the Institute.

7. (1.) Any casual vacancy in the Board, howsoever caused, shall be filled within three months by the society or authority that appointed the member whose place has become vacant, and if not filled within that time the vacancy shall be filled by the Board.

(2.) Any person appointed to fill a casual vacancy shall only hold office for such period as his predecessor would have held office under this Act.

8. (1.) Annual meetings of the Board shall be held in the month of January in each year, the date and place of such annual meeting to be fixed at the previous annual meeting.

(2.) The Board may meet during the year at such other times and places as it deems necessary.

(3.) At each annual meeting the President shall present to the meeting a report of the work of the Institute for the year preceding, and a balance-sheet, duly audited, of all sums received and paid on behalf of the Institute.

9. The Board may from time to time, as it sees fit, make arrangements for the holding of general meetings of members of the Institute, at times and places to be arranged, for the reading of scientific papers, the delivery of lectures, and for the general promotion of science in New Zealand by any means that may appear desirable.

10. The Minister of Finance shall from time to time, without further appropriation than this Act, pay to the Board the sum of five hundred pounds in each financial year, to be applied in or towards payment of the general current expenses of the Institute.

11. Forthwith upon the making of any regulations or the publication of any Transactions, the Board shall transmit a copy thereof to the Minister of Internal Affairs, who shall lay the same before Parliament if sitting, or if not, then within twenty days after the commencement of the next ensuing session thereof.

SCHEDULE.

Enactments consolidated.

1903, No. 48.—The New Zealand Institute Act, 1903.

REGULATIONS.

THE following are the regulations of the New Zealand Institute under the Act of 1903:—

The word "Institute" used in the following regulations means the New Zealand Institute as constituted by the New Zealand Institute Act, 1903.

INCORPORATION OF SOCIETIES.

1. No society shall be incorporated with the Institute under the provisions of the New Zealand Institute Act, 1903, unless such society shall consist of not less than twenty-five members, subscribing in the aggregate

[1] *New Zealand Gazette*, 14th July, 1904.

a sum of not less than £25 sterling annually for the promotion of art, science, or such other branch of knowledge for which it is associated, to be from time to time certified to the satisfaction of the Board of Governors of the Institute by the President for the time being of the society.

2. Any society incorporated as aforesaid shall cease to be incorporated with the Institute in case the number of the members of the said society shall at any time become less than twenty-five, or the amount of money annually subscribed by such members shall at any time be less than £25.

3. The by-laws of every society to be incorporated as aforesaid shall provide for the expenditure of not less than one-third of the annual revenue in or towards the formation or support of some local public museum or library, or otherwise shall provide for the contribution of not less than one-sixth of its said revenue towards the extension and maintenance of the New Zealand Institute.

4. Any society incorporated as aforesaid which shall in any one year fail to expend the proportion of revenue specified in Regulation No. 3 aforesaid in manner provided shall from henceforth cease to be incorporated with the Institute.

Publications.

5. All papers read before any society for the time being incorporated with the Institute shall be deemed to be communications to the Institute, and then may be published as Proceedings or Transactions of the Institute, subject to the following regulations of the Board of the Institute regarding publications:—

(*a.*) The publications of the Institute shall consist of—

(1.) A current abstract of the proceedings of the societies for the time being incorporated with the Institute, to be intituled "Proceedings of the New Zealand Institute";

(2.) And of transactions comprising papers read before the incorporated societies (subject, however, to selection as hereinafter mentioned), and of such other matter as the Board of Governors shall from time to time determine to publish, to be intituled "Transactions of the New Zealand Institute."

(*b.*) The Board of Governors shall determine what papers are to be published.

(*c.*) Papers not recommended for publication may be returned to their authors if so desired.

(*d.*) All papers sent in for publication must be legibly written, typewritten, or printed.

(*e.*) A proportional contribution may be required from each society towards the cost of publishing Proceedings and Transactions of the Institute.

(*f.*) Each incorporated society will be entitled to receive a proportional number of copies of the Transactions and Proceedings of the New Zealand Institute, to be from time to time fixed by the Board of Governors.

Management of the Property of the Institute.

6. All property accumulated by or with funds derived from incorporated societies, and placed in charge of the Institute, shall be vested in the Institute, and be used and applied at the discretion of the Board of

Governors for public advantage, in like manner with any other of the property of the Institute.

7. All donations by societies, public Departments, or private individuals to the Institute shall be acknowledged by a printed form of receipt, and shall be entered in the books of the Institute provided for that purpose, and shall then be dealt with as the Board of Governors may direct.

Honorary Members.

8. The Board of Governors shall have power to elect honorary members (being persons not residing in the Colony of New Zealand), provided that the total number of honorary members shall not exceed thirty.

9. In case of a vacancy in the list of honorary members, each incorporated society, after intimation from the Secretary of the Institute, may nominate for election as honorary member one person.

10. The names, descriptions, and addresses of persons so nominated, together with the grounds on which their election as honorary members is recommended, shall be forthwith forwarded to the President of the New Zealand Institute, and shall by him be submitted to the Governors at the next succeeding meeting.

General Regulations.

11. Subject to the New Zealand Institute Act, 1908, and to the foregoing rules, all societies incorporated with the Institute shall be entitled to retain or alter their own form of constitution and the by-laws for their own management, and shall conduct their own affairs.

12. Upon application signed by the President and countersigned by the Secretary of any society, accompanied by the certificate required under Regulation No. 1, a certificate of incorporation will be granted under the seal of the Institute, and will remain in force as long as the foregoing regulations of the Institute are complied with by the society.

13. In voting on any subject the President is to have a deliberate as well as a casting vote.

14. The President may at any time call a meeting of the Board, and shall do so on the requisition in writing of four Governors.

15. Twenty-one days' notice of every meeting of the Board shall be given by posting the same to each Governor at an address furnished by him to the Secretary.

16. In case of a vacancy in the office of President, a meeting of the Board shall be called by the Secretary within twenty-one days to elect a new President.

17. The Governors for the time being resident or present in Wellington shall be a Standing Committee for the purpose of transacting urgent business and assisting the officers.

18. The Standing Committee may appoint persons to perform the duties of any other office which may become vacant. Any such appointment shall hold good until the next meeting of the Board, when the vacancy shall be filled.

19. The foregoing regulations may be altered or amended at any annual meeting, provided that notice be given in writing to the Secretary of the Institute not later than the 30th November.

THE HUTTON MEMORIAL MEDAL AND RESEARCH FUND.

Resolved by the Board of Governors of the New Zealand Institute that—

1 The funds placed in the hands of the Board by the committee of subscribers to the Hutton Memorial Fund be called "The Hutton Memorial Research Fund," in memory of the late Captain Frederick Wollaston Hutton, F.R.S. Such fund shall consist of the moneys subscribed and granted for the purpose of the Hutton Memorial, and all other funds which may be given or granted for the same purpose.

2. The funds shall be vested in the Institute. The Board of Governors of the Institute shall have the control of the said moneys, and may invest the same upon any securities proper for trust moneys.

3. A sum not exceeding £100 shall be expended in procuring a bronze medal to be known as "The Hutton Memorial Medal."

4. The fund, or such part thereof as shall not be used as aforesaid, shall be invested in such securities as aforesaid as may be approved of by the Board of Governors, and the interest arising from such investment shall be used for the furtherance of the objects of the fund.

5. The Hutton Memorial Medal shall be awarded from time to time by the Board of Governors, in accordance with these regulations, to persons who have made some noticeable contribution in connection with the zoology, botany, or geology of New Zealand.

6. The Board shall make regulations setting out the manner in which the funds shall be administered. Such regulations shall conform to the terms of the trust.

7. The Board of Governors may, in the manner prescribed in the regulations, make grants from time to time from the accrued interest to persons or committees who require assistance in prosecuting researches in the zoology, botany, or geology of New Zealand.

8. There shall be published annually in the "Transactions of the New Zealand Institute" the regulations adopted by the Board as aforesaid, a list of the recipients of the Hutton Memorial Medal, a list of the persons to whom grants have been made during the previous year, and also, where possible, an abstract of researches made by them.

Regulations under which the Hutton Memorial Medal shall be awarded and the Research Fund administered.

1. Unless in exceptional circumstances, the Hutton Memorial Medal shall be awarded not oftener than once in every three years; and in no case shall any medal be awarded unless, in the opinion of the Board, some contribution really deserving of the honour has been made.

2. The medal shall not be awarded for any research published previous to the 31st December, 1906.

3. The research for which the medal is awarded must have a distinct bearing on New Zealand zoology, botany, or geology.

4. The medal shall be awarded only to those who have received the greater part of their education in New Zealand or who have resided in New Zealand for not less than ten years.

5. Whenever possible, the medal shall be presented in some public manner.

6. The Board of Governors may, at an annual meeting, make grants from the accrued interest of the fund to any person, society, or committee for the encouragement of research in New Zealand zoology, botany, or geology.

7. Applications for such grants shall be made to the Board before the 30th September.

8. In making such grants the Board of Governors shall give preference to such persons as are defined in regulation 4.

9. The recipients of such grants shall report to the Board before the 31st December in the year following, showing in a general way how the grant has been expended and what progress has been made with the research.

10. The results of researches aided by grants from the fund shall, where possible, be published in New Zealand.

11. The Board of Governors may from time to time amend or alter the regulations, such amendments or alterations being in all cases in conformity with resolutions 1 to 4.

Award of the Hutton Memorial Medal.

1911. Professor W. B. Benham, D.Sc., F.R.S., University of Otago—For researches in New Zealand zoology.

Grant from the Hutton Memorial Research Fund.

1911. To Professor C. Chilton, Canterbury College—£10 for the preparation of illustrations for a revision of the *Crustacea* of New Zealand.

NEW ZEALAND INSTITUTE.

ESTABLISHED UNDER AN ACT OF THE GENERAL ASSEMBLY OF NEW ZEALAND INTITULED THE NEW ZEALAND INSTITUTE ACT, 1867, RECONSTITUTED BY AN ACT OF THE GENERAL ASSEMBLY OF NEW ZEALAND UNDER THE NEW ZEALAND INSTITUTE ACT, 1903, AND CONTINUED BY THE NEW ZEALAND INSTITUTE ACT, 1908

BOARD OF GOVERNORS.

EX OFFICIO.

His Excellency the Governor.
The Hon. the Minister of Internal Affairs

NOMINATED BY THE GOVERNMENT.

A. Hamilton; E. Tregear, F.R.G.S.; John Young; Charles A. Ewen.

ELECTED BY AFFILIATED SOCIETIES.

Wellington: Martin Chapman, K.C.; Professor T. H. Easterfield, M.A., Ph.D. Auckland: D. Petrie, M.A.; J. Stewart, C.E. Napier: H. Hill, B.A., F.G.S. Christchurch: R. Speight, M.A., M.Sc., F.G.S.; F. W. Hilgendorf, D.Sc. Westland: (vacant). Nelson: L. Cockayne, Ph.D. Otago: Professor W. B. Benham, D.Sc., F.R.S.; G. M. Thomson, F.L.S., F.C.S., M.P. Manawatu: K. Wilson, M.A.

OFFICERS FOR THE YEAR 1911.

PRESIDENT: T. F. Cheeseman, F.L.S.

HON. TREASURER: Professor T. H. Easterfield, M.A., Ph.D.

HON. EDITOR: C. Chilton, M.A., D.Sc., F.L.S.

SECRETARY: B. C. Aston, F.I.C., F.C.S.

AFFILIATED SOCIETIES.	DATE OF AFFILIATION.
Wellington Philosophical Society	10th June, 1868.
Auckland Institute	10th June, 1868.
Philosophical Institute of Canterbury ...	22nd October, 1868.
Otago Institute	18th October, 1869.
Westland Institute	21st December, 1874.
Hawke's Bay Philosophical Institute ...	31st March, 1875.
Southland Institute	21st July, 1880.
Nelson Institute	20th December, 1883.
Manawatu Philosophical Society	16th January, 1904.

FORMER HONORARY MEMBERS.

1870.

Agassiz, Professor Louis.
Drury, Captain Byron, R.N.
Flower, Professor W.H., F.R.S.
Hochstetter, Dr. Ferdinand von.
Mueller, Ferdinand von, M.D., F.R.S., C.M.G.
Owen, Professor Richard, F.R.S.
Richards, Rear-Admiral G. H

1871.

Darwin, Charles, M.A., F.R.S.
Gray, J. E., Ph.D., F.R.S.
Lindsay, W. Lauder, M.D., F.R.S.E.

1872.

Grey, Sir George, K.C.B
Huxley, Thomas H., LL.D., F.R.S.
Stokes, Vice-Admiral J. L.

1873.

Bowen, Sir George Ferguson, G.C.M.G.
Cambridge, the Rev. O. Pickard, M.A., C.M.Z.S
Lyell, Sir Charles, Bart., D.C.L., F.R.S

1874.

McLachlan, Robert, F.L.S.
Newton, Alfred, F.R.S.
Thomson, Professor Wyville, F.R.S.

1875.

Filhol, Dr. H.
Rolleston, Professor G., M.D., F.R.S.

1876.

Clarke, Rev. W. B., M.A., F.R.S.
Etheridge, Professor R., F.R.S.

1877.

Baird, Professor Spencer F.
Weld, Frederick A., C.M.G.

1878.

Garrod, Professor A. H., F.R.S.
Müller, Professor Max, F.R.S.
Tenison-Woods, Rev. J. E., F.L.S.

1880.

The Most Noble the Marquis of Normanby, G.C.M.G.

1883.

Carpenter, Dr. W. B., C.B., F.R.S.
Ellery, Robert L. J., F.R.S.
Thomson, Sir William, F.R.S.

1885.

Gray, Professor Asa.
Sharp, Richard Bowdler, M.A., F.R.S.

1888.

Beneden, Professor J. P. van
Ettingshausen, Baron von.
McCoy, Professor F., D.Sc., C.M.G F.R.S.

1890.

Riley, Professor C. V.

1891.

Davis, J. W., F.G.S., F.L.S.

1894.

Codrington, Rev. R. H., D.D.

1895.

Mitten, William, F.R.S.

1896.

Langley, S. P.

1900.

Agardh, Dr. J. G.

1901.

Eve, H. W., M.A.
Howes, G. B., LL.D., F.R.S.

FORMER MANAGER AND EDITOR.

[Under the New Zealand Institute Act, 1867.]

1867–1903.

Hector, Sir James, M.D., K.C.M.G., F.R.S.

PAST-PRESIDENTS.

1903–4.

Hutton, Captain Frederick Wollaston, F.R.S.

1905–6.

Hector, Sir James, M.D., K.C.M.G., F.R.S.

1907–8.

Thomson, George Malcolm, F.L.S., F.C.S., M.P.

1909–10.

A. Hamilton, F.L.S.

HONORARY MEMBERS.

1870.

Finsch, Otto, Professor, Ph.D., Braunschweig, Germany.
Hooker, Sir J. D., G.C.S.I., C.B., M.D. F.R.S., O.M., Royal Gardens, Kew.

1873.

Günther, A., M.D., M.A., Ph.D., F.R.S., Litchfield Road, Kew Gardens, Surrey.

1875.

SCLATER, PHILIP LUTLEY, M.A., Ph.D., F.R.S., Zoological Society, London.

1876.

BERGGREN, Dr. S., Lund, Sweden.

1877.

SHARP, Dr. D., University Museum, Cambridge.

1885.

WALLACE, A. R., F.L.S., O.M., Broadstone, Wimborne, England.

1890.

NORDSTEDT, Professor OTTO, Ph.D., University of Lund, Sweden.

LIVERSIDGE, Professor A., M.A., F.R.S., Sydney.

1891.

GOODALE, Professor G. L., M.D., LL.D., Harvard University, Massachusetts, U.S.A.

1894.

DYER, Sir W. T. THISELTON, K.C.M.G., C.I.E., LL.D., M.A., F.R.S., Royal Gardens, Kew.

CODRINGTON, Rev. R. H., D.D., Wadhurst Rectory, Sussex, England.

1896.

LYDEKKER, RICHARD, B.A., F.R.S., British Museum, South Kensington.

1900.

AVEBURY, Lord, P.C., F.R.S., High Elms, Farnborough, Kent.

MASSEE, GEORGE, F.L.S., F.R.M.S., Royal Botanic Gardens, Kew.

1901.

GOEBEL, Dr. CARL, University of Munich.

1902.

SARS, Professor G. O., University of Christiania, Norway.

1903.

KLOTZ, Professor OTTO J., 437 Albert Street, Ottawa, Canada.

1904.

RUTHERFORD, Professor E., D.Sc., F.R.S., Victoria University of Manchester.

DAVID, Professor T. EDGEWORTH, F.R.S., Sydney University, N.S.W.

1906.

BEDDARD, F. E., F.R.S., Zoological Society, London.

MILNE, J., F.R.S., Isle of Wight, England.

BRADY, G. S., F.R.S., University of Durham, England.

1907.

DENDY, Dr., F.R.S., King's College, University of London, England.

DIELS, L., Ph.D., Marburg.

MEYRICK, E., B.A., F.R.S., Marlborough College, England.

STEBBING, Rev. T. R. R., F.R.S., Tunbridge Wells, England.

1909.

DARWIN, Sir George, F.R.S., Cambridge.

1910.

BRUCE, Dr. W. S., Edinburgh.

ORDINARY MEMBERS.

WELLINGTON PHILOSOPHICAL SOCIETY.

[* Life members. † Honorary members.]

Adams, C. E., M.Sc., A.I.A., F.R.A.S.
Adams, C. W., Lower Hutt
Adkin, G. Leslie, Levin
Aston, Rev. A. E., Te Awamutu
Aston, B. C., F.C.S., F.I.C.
Atkinson, Esmond H.
Baldwin, E. S.
Barraud, W. F.
Beetham, W. H., Masterton
Bell, E. D.
Bell, H. D., K.C.
Berry, C. G. G.
Blair, J. R.
Borghetti, Dr. E.
Brandon, A. de B., B A.
Campbell, O. N., Hamilton
Carter, W. H., jun.
Chapman, Martin, K.C.
Christie, Mrs. H. M.
Chudleigh, E. R., Orongomairoa, Waihou
Climie, J. D., Lower Hutt
Cockayne, A. H.
Cotton, C. A., M.Sc.
Crawford, Alex. D.
Carter, F., M.A.
Downes, T. W., Wanganui
Dymock, E. R.
Easterfield, Professor T. H., M.A., Ph.D.
Ewen, Charles A.
Fergusoñ, W., M.Inst.C.E.
Field, H. C., Aramoho, Wanganui
FitzGerald, Gerald, A.M.Inst.C.E.
Fleming, T. R., M.A., LL.B.
Fletcher, Rev. H. J., Taupo
Fraser, Hon. F. H., M.L.C.
Freeman, H. J.
Freyberg, Cuthbert
Gatenby, James B.
Gifford, A. C., M.A.
Gill, Thomas H., M.A., LL.B.
Girdlestone, H. E.
Graham, K. M., A.O.S.M.
Gray, William, M.A., B.Sc.
Hadfield, E. F.
Hamilton, Augustus, F.L.S.†
Hanify, H. P.
Harding, R. Coupland
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Hastie, Miss J. A., London, England*
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Cabinet, The Members of, Wellington.
Executive Library, Wellington.
Free Public Library, Auckland.
" Christchurch.
" Dunedin.
" Wellington.
Government Printer and publishing staff (6 copies).
Library, Auckland Institute, Auckland.
" Auckland Museum, Auckland.
" Biological Laboratory, Canterbury College, Christchurch.
" Biological Laboratory, University College, Auckland.
" Biological Laboratory, University of Otago, Dunedin.
" Biological Laboratory, Victoria College, Wellington.
" Canterbury Museum, Christchurch.
" Dunedin Athenæum.
" General Assembly, Wellington (2 copies).
" Hawke's Bay Philosophical Institute, Napier.
" Manawatu Philosophical Society, Palmerston North.
" Nelson College.
" Nelson Institute, Nelson.
" New Zealand Geological Survey.
" New Zealand Institute of Surveyors.
" New Zealand Institute, Wellington.
" Otago Institute, Dunedin.
" Otago Museum, Dunedin.
" Otago School of Mines, Dunedin.
" Philosophical Institute of Canterbury, Christchurch.
" Polynesian Society, New Plymouth.
Portobello Fish-hatchery, Dunedin.
" Reefton School of Mines.
" Thames School of Mines.
" University College, Auckland.
" University College, Christchurch.
" University of Otago, Dunedin.
" Victoria College, Wellington.
" Wanganui Museum.
" Wellington Philosophical Society.
" Westland Institute, Hokitika.

Great Britain.

Anthropological Institute of Great Britain and Ireland, London.
British Association for the Advancement of Science, London.
British Museum Library, London.
" Natural History Department, South Kensington, London S.W.

Cambridge Philosophical Society, Cambridge University
Colonial Office, London.
Clifton College, Bristol, England.
Entomological Society, London.
Geological Magazine, London.
Geological Society, Edinburgh.
" London.
Geological Survey of the United Kingdom, London
High Commissioner for New Zealand, London.
Imperial Institute, London.
Institution of Civil Engineers, London.
International Catalogue of Scientific Literature, London.
Leeds Geological Association, Meanwood, Leeds.
Linnæan Society, London.
Literary and Philosophical Society, Liverpool.
Liverpool Biological Society.
Marine Biological Association of the United Kingdom, Plymouth.
Natural History Society, Glasgow.
" Marlborough College, England.
Nature, The Editor of, London.
Norfolk and Norwich Naturalist Society, Norwich.
North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne.
Patent Office Library, London.
Philosophical Society of Glasgow.
Philosophical Society of Leeds, England.
Royal Asiatic Society, London.
Royal Botanic Garden Library, Edinburgh.
Royal College of Physicians, Edinburgh.
Royal Colonial Institute, London.
Royal Geographical Society, London.
Royal Irish Academy, Dublin.
Royal Physical Society, Edinburgh.
Royal Society, Dublin.
" Edinburgh.
" London.
Royal Society of Literature of the United Kingdom, London.
Royal Statistical Society, London.
School Library Committee, Eton, England.
" Rugby, England
University Library, Cambridge, England.
" Edinburgh.
" Oxford, England.
Victoria College, Manchester.
Victoria Institute, London.
William Wesley and Son, London (Agents)
Zoological Society, London.

British North America.

Canadian Institute, Toronto.
Geological and Natural History Survey of Canada, Ottawa.
Hamilton Scientific Association, Hamilton, Canada.
Institute of Jamaica, Kingston.
Literary and Historical Society of Quebec, Canada East.
Natural History Society of New Brunswick, St. John's.

Nova-Scotian Institute of Natural Science, Halifax.
Ottawa Literary and Scientific Society, Ottawa

South Africa.

Free Public Library, Cape Town.
South African Philosophical Society, Cape Town
South African Association for the Advancement of Science, Cape Town
South African Museum, Cape Town.
Rhodesia Museum, Bulawayo, South Africa

India.

Asiatic Society of Bengal, Calcutta.
Colombo Museum, Ceylon.
Geological Survey of India, Calcutta
Natural History Society, Bombay.
Raffles Museum, Singapore.

Queensland.

Geological Society of Australasia, Queensland Branch, Brisbane.
Geological Survey Office, Brisbane.
Library, Botanic Gardens, Brisbane.
Queensland Museum, Brisbane.
Royal Society of Queensland, Brisbane

New South Wales.

Agricultural Department, Sydney.
Australasian Association for the Advancement of Science, Sydney.
Australian Museum Library, Sydney.
Department of Mines, Sydney.
Engineering Association of New South Wales, Sydney.
Library, Botanic Gardens, Sydney.
Linnæan Society of New South Wales, Sydney.
Public Library, Sydney.
Royal Geographical Society of Australasia, N.S W. Branch, Sydney.
Royal Society of New South Wales, Sydney.
University Library, Sydney.

Victoria.

Australian Institute of Mining Engineers, Melbourne.
Field Naturalists' Club, Melbourne.
Geological Survey of Victoria, Melbourne.
Gordon Technical College, Geelong.
Legislative Library, Melbourne.
Public Library, Melbourne.
Royal Society of Victoria, Melbourne.
University Library, Melbourne.
Victorian Institute of Surveyors.

Tasmania.

Public Library of Tasmania, Hobart.
Royal Society of Tasmania, Hobart.

South Australia.

Royal Society of South Australia, Adelaide.
University Library, Adelaide.

Russia.

Finskoie Uchonoie Obshchestvo, Finnish Scientific Society, Helsingfors.
Imper. Moskofskoie Obshchestvo Iestestvo-Ispytatelei, Imperial Moscow Society of Naturalists.
Kiefskoie Obshchestvo Iestestvo-Ispytatelei, Kief Society of Naturalists.

Norway.

Bergens Museum, Bergen.
University of Christiania.

Sweden.

Geological Survey of Sweden, Stockholm.
Royal Academy of Science, Stockholm.

Denmark.

Natural History Society of Copenhagen.
Royal Danish Academy of Sciences and Literature of Copenhagen.

Germany.

Botanischer Verein der Provinz Brandenburg, Berlin.
Königliche Bibliothek, Berlin.
Königliche Physikalisch-Oekonomische Gesellschaft, Königsberg, E. Prussia.
Königliches Zoologisches und Anthropologisch-Ethnographisches Museum, Dresden.
Naturhistorischer Verein, Bonn.
Naturhistorisches Museum, Hamburg.
Naturwissenschaftlicher Verein, Bremen.
Naturwissenschaftlicher Verein, Frankfort-an-der-Oder.
Rautenstrauch-Joest-Museum (Städtisches Museum für Völkerkunde), Cologne.
Redaktion des Biologischen Central-Blatts, Erlangen.
Senckenbergische Naturforschende Gesellschaft, Frankfurt-am-Main.
Verein für Vaterländische Naturkunde in Württemburg, Stuttgart.

Austria.

K.K. Central-Anstalt für Meteorologie und Erdmagnetismus, Vienna.
K.K. Geologische Reichsanstalt, Vienna.

Belgium and the Netherlands.

Musée Teyler, Haarlem.
Académie Royal des Sciences, des Lettres, et des Beaux-Arts de Belgique, Brussels.
La Société Royale de Botanique de Belgique, Brussels.

Switzerland.

Musée d'Histoire Naturelle de Genève.
Naturforschende Gesellschaft (Société des Sciences Naturelles), Bern.

France

Bibliothèque Nationale, Paris.
Musée d'Histoire Naturelle de Bordeaux
Musée d'Histoire Naturelle, Paris.
Société Entomologique de France, Paris.
Société de Géographie, Paris.
Société Zoologique de France, Paris.

Italy.

Biblioteca ed Archivio Tecnico, Rome.
Museo di Geologia e Paleontologia del R. Instituto di Studi Superiori, Florence.
Museo di Zoologia e di Anatomia Comparata della R. Università, Turin.
Orto e Museo Botanico (R. Instituto di Studi Superiori), Florence.
R. Accademia di Scienze, Lettre, ed Arti, Modena.
R. Accademia dei Lincei, Rome.
Stazione Zoologica di Napoli, Naples.
Società Africana d'Italia, Naples.
Società Geografica Italiana, Rome.
Società Toscana di Scienze Naturali, Pisa.

United States of America.

Academy of Natural Sciences, Buffalo, State of New York.
" Davenport, Iowa.
" Library, Philadelphia.
" San Francisco.
American Geographical Society, New York.
American Institute of Mining Engineers, Philadelphia.
American Museum of Natural History, New York.
American Philosophical Society, Philadelphia.
Boston Society of Natural History.
Connecticut Academy, New Haven.
Department of Agriculture, Washington, D.C.
Field Museum of Natural History, Chicago.
Franklin Institute, Philadelphia.
Johns Hopkins University, Baltimore.
Missouri Botanical Gardens, St. Louis, Mo.
Museum of Comparative Zoology, Cambridge, Mass.
Natural History Museum, Central Park, New York.
New York Academy of Sciences.
Philippine Museum, Manila.
Rochester Academy of Sciences.
Smithsonian Institution, Washington, D.C.
Stanford University, California.
Tufts College, Massachusetts.
United States Geological Survey, Washington, D.C.
University of Montana, Missoula.
Wagner Free Institute of Science of Philadelphia.
Washington Academy of Sciences.

Brazil.

Museo Paulista, Sao Paulo.
Escola de Minas, Rio de Janeiro

Argentine Republic.

Sociedad Cientifica Argentina, Buenos Ayres.

Uruguay.

Museo Nacional, Monte Video.

Japan.

College of Literature, Imperial University of Japan, Tokyo.
College of Science, Imperial University of Japan, Tokyo.

Hawaii.

Bernice Pauahi Bishop Museum, Honolulu.
National Library, Honolulu.

Java.

Society of Natural Science, Batavia.

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